5-2014

Comparison of the Design-Bid-Build and Construction Manager at Risk Project Delivery Methods Utilized for the Construction of Public Schools

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COMPARISON OF THE DESIGN-BID-BUILD AND CONSTRUCTION MANAGER AT-RISK PROJECT DELIVERY METHODS UTILIZED FOR THE CONSTRUCTION OF PUBLIC SCHOOLS

A Dissertation
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy
Planning, Design, and the Built Environment

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May 2014

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ABSTRACT

According to Fails Management Institute (FMI) and the Construction Management Association of America (CMAA), the most widely utilized and accepted project delivery method is the Design-Bid-Build method (FMI/CMAA, 2010). However, proponents of alternative methods, such as Construction Manager at-Risk (CM at-Risk), believe that these methods offer the promise of better performance when utilized on certain types of projects (AIA-AGC, 2011; Konchar & Sanvido, 1998). Furthermore, it is said that modern projects are subject to increased risk due to complex designs and technology, involvement of multiple and diverse parties, and increased budgetary and schedule pressure, and that "choosing an appropriate delivery (method) is often the key to success—or the source of failure" (Demkin & AIA, 2009, p. 492).

In order to empower decision makers responsible for constructing new public schools (K-12), this study sought to determine how the CM at-Risk project delivery method performed in comparison to the Design-Bid-Build method on school projects utilizing the performance metrics of construction cost, time, quality, and claims. The research was carried out over a two year period from 2012 to 2014 and included a two-stage data collection effort consisting of a historical document review and assemblage and a survey of district managers regarding the performance of 137 Elementary, Middle, and High school projects constructed in Florida, Georgia, North Carolina, and South Carolina. Data analysis was completed utilizing two group t-tests and chi-square (x^2) distributions based on a 95% confidence interval.

The analysis indicated that public school projects constructed utilizing the CM at-Risk method did not produce the purported cost, schedule, productivity, or risk reduction benefits. The mean values of all cost performance metrics for CM at-Risk projects were significantly higher than those of their Design-Bid-Build counterparts. Analysis of schedule performance metrics provided no statistically significant differences with regard to school project durations. Similarly, statistically significant results were not obtained through examination of risk, productivity, cost growth, and schedule growth metrics.

Conversely, the analysis indicated that CM at-Risk school projects produced significantly higher levels of product and service quality as reported by district construction managers in almost every category examined. However, regardless of the project delivery method being employed, almost all managers were satisfied with both the service and product quality provided during construction of their completed school projects. The differences observed were merely indications of the *degree of quality satisfaction* with the products and services rendered.

Possible reasons that the purported CM at-Risk benefits of cost, schedule, productivity, and risk reduction were not manifested in the results of this study could be attributable in part to many issues including: incorrect selection of the most appropriate project delivery method by administrators and district construction managers, utilization of value added designs and equipment in some schools that may have influenced costs and other metrics, contingency management practices, collaborative influences on the scheduling process, lack of respect and appreciation for the differing factors related to each project delivery method, and unrealistic expectations of the decision makers. Based on these issues and the mixed results of the empirical findings as noted above, it is recommended that decision makers should utilize project delivery method selection as part of an overall value assessment strategy for the construction of their public school projects.

The greatest limitation of this study and others conducting research in the field of public school construction is the lack of an existing cohesive dataset. There are many intervening factors involved with the lack of cohesive data including the local control of public school funding and construction programs and the disparate policy issues at the district and state levels. Collection and maintenance of public school construction data should be the topic for future research along with a study designed to develop a systematic approach for determining levels of public school construction complexity.

In conclusion, it is of primary importance for those in project delivery method decision-making capacities that careful considerations are given to all aspects of the design and construction scenario. Additionally, a variety of delivery methods must be made available in order to facilitate the appropriate delivery method selection and thus, the proper management of the project scenario in order to obtain superior performance when constructing public schools.

DEDICATION

The work of this dissertation is dedicated to my wife, Suzanne. In addition to generously providing the time and support necessary to perform the work required to complete the research and dissertation, she has also provided the freedom to enjoy the overall experience of returning to graduate school. I am sincerely grateful for her love and support throughout the entire process, and I look forward to returning the favor by serving her now and in the future. Baby, I will start working on that porch just as soon as we get home.

ACKNOWLEDGEMENTS

I would first like to take a moment to recognize my colleagues in the PDBE program, it being unimportant to mention anyone by name, except that Deborah should be mentioned first, but that's it, except for Lynn being next, of course. I would like to say that everyone, including the students and professors, have always been willing to provide support, praise, and advice whenever necessary. Having these colleagues to lean on and relate to when times were rough enabled me to keep things in perspective (usually) and enjoy the overall experience. Thank you for the friendship and encouragement. I wish you all well with your lives and careers.

I would like to acknowledge Dr. Mickey Lauria for accepting me into the program and launching me back into graduate school with my initial course in planning that first semester. I appreciate the challenges you put before me and the advice you provided to assist in the management of my degree path. I encourage my PDBE colleagues to engage this powerful resource while navigating their way through the program.

I would like to individually thank the members of my dissertation committee. I offer thanks to the Chairman, Dr. Dennis Bausman, for providing the initial research direction, ongoing encouragement, and steadfast guidance and coffee during our many hours of discussion. Thanks to Dr. Roger Liska for the direct comments and feedback during many chapters of proof reading and editing. To Dr. Hoke Hill, for his genuine interest with the topic, the statistics tutelage, and the SAS program training he provided. To Dr. Barry Nocks, for helping me explore, understand, and explain the fundamental principles of collaboration. And finally, thanks to Mike Kenig, for his intense devotion and tireless enthusiasm toward improving the construction industry and specifically, to the study of project delivery systems for construction.

Next, it is important for me to thank those in the CSM Department for welcoming me onboard and into the undergraduate teaching realm. Not only was this a source of academic advisement and funding assistance, it was an opportunity for me to step back and learn a great deal about the construction industry. Additionally, it allowed me an introduction and audience with the undergraduate students, and I look forward to assisting them whenever our paths cross in the future.

In closing, I would like to thank a few of those behind the scenes players without which, none of this would have been possible. The incredible support staff at Clemson University and Lee Hall, most notably Deborah Anthony of the CSM Department, Kathy Edwards and Gypsey Teague in the Lee Hall Library, and Richard Woodward (building manager) and Chris Wilson (the computer guy). Thanks for keeping the machine in operation.

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CHAPTER 1:

INTRODUCTION

1.1 State of the Industry

Dramatic changes have affected the construction industry over the past several decades and owners, architects, and contractors alike have been searching for methods to construct projects in a manner that improves performance while reducing risk. The construction industry is an increasingly complex, fragmented, and dynamic industry (Saporita, 2006; Zaghloul & Hartman, 2003; Akintoye & MacLeod, 1997; Gordon, 1994; Kangari, 1995; Al-Bahar, 1990). Modern projects involve hundreds of individuals with dozens of project staff members in decision-making capacities from multiple firms and disciplines, each with their own separate focus on project planning, designing, and construction. Construction projects are unique (Kenig, 2011) and are usually tailored to meet the specific needs of the owner, often requiring advanced materials and technologies in order to complete their assembly. Construction sites are often located in difficult terrain with confined access, and the projects must be constructed in various weather conditions under hazardous conditions. School construction projects are particularly complex due in part to the multiple parties, planning, timing, and statutory issues (Vincent & McKoy, 2008). These issues serve to frustrate decision makers and challenge those in the industry to continually improve existing methods, processes, and procedures utilized to complete construction projects.

Recent economic fluctuations since 2007 have forced federal, state, and municipal governments to reduce budgets, while at the same time, increasing costs, growing populations, and changing demographics have increased demands on aging and outdated facilities (Abramson, 2012; Oliff, Mai, & Palacios, 2012; McNichol, Oliff, & Johnson, 2011; US Census Bureau, 2011; FMI/CMAA, 2007). Since 1995, more than $310 billion has been spent on capital projects for education with more than $174 billion of that spent on new school facilities, $6.2 billion of which occurred in 2012 (Abramson, 2013). During this same period the median cost per square foot to construct educational facilities has doubled (Ibid). Budget shortfalls, slow projected economic growth, and reduced tax revenues will continue to place pressure on capital expenditures for public school systems (Oliff, Mai, & Palacios, 2012; McNichol, Oliff, & Johnson, 2011).

In addition to these issues, a recent National Research Council (NRC) study reports that construction productivity has remained flat or has fallen, while productivity gains have been made in manufacturing and other industries (NRC, 2009). The report further states that government entities and private owners that make large capital improvement expenditures have the greatest opportunity to influence productive changes in the construction industry while at the same time, benefitting most from the lower cost and improved quality of these projects. The report calls for the strategic and collaborative implementation of technology and "more effective interfacing of people, processes, materials, equipment and information" (NRC, 2009, p. 1) among other recommendations. The private sector of the construction industry has turned to increased utilization of alternative delivery methods in an effort to reduce costs and improve efficiency (FMI/CMAA, 2005, 2007, 2010). Proponents of alternative methods believe that utilization of these methods with new contractual requirements can foster innovative techniques and collaborative work between owners, contractors, and architects and in turn, improve construction productivity, lower costs, save time, and improve project quality (NRC, 2009; O'Connor, 2009; Kenig, 2011; Konchar & Sanvido, 1998).

1.2 Problem Statement

The motivation behind this study was to address the ongoing question within the construction industry: Which project delivery method performs at a higher level in terms of cost, time, quality, and claims when utilized for the construction of public schools? Since it is the duty of government to serve the needs of the people, it is imperative that government agencies, acting in the capacity of public owners, procure and deliver projects in an efficient and effective manner. And, in order for legislative bodies, government agencies, and public employees to make informed, critical decisions regarding the construction of public schools, they require current, relevant, and significant performance data and a thorough working knowledge of the factors affecting school construction (Vincent & McKoy, 2008). The selection of the appropriate project delivery methods is one of these factors.

A review of the literature revealed that a limited amount of empirical research has been conducted on project delivery methods for the construction of public school projects. A recent cost analysis of California public schools conducted by the University of California, Berkley, for the American Institute of Architects (AIA) stated that the difficulty of their task was complicated by "the lack of quality data and information on school construction cost, schedule, and scope, (and) also because little research on these processes exists" (Ibid, p. 3). Foundational research on the performance of alternative methods of project delivery was conducted by Konchar (1997), Konchar and Sanvido (1998), and Bennett, Pothecary, and Robinson (1996) and those studies continue to be the most widely cited and accepted. However, the research of Rojas and Kell (2008) and Williams (2003) provided evidence of conflicting results with that of Konchar and Sanvido (1998). Furthermore, Williams (2003) was critical of the statistical analysis and validity of portions of the Konchar and Sanvido (1998) work due to wide variations in the cost, size, and complexity of the projects included within the dataset. These reports revealed that the Konchar and Sanvido (1998) research does not include the proper mix of projects required to meet the needs of the current study. Moreover, the Williams (2003) and Rojas and Kell (2008) studies utilized data from projects located exclusively in the northwestern US. Due to the local climate, terrain, or other educational factors associated with this region, designs of these projects may serve to differentiate them from those in the current study area. Additionally, while the Rojas and Kell (2008) research was focused on public school projects, the wide variations in the ages of their project data (1-20 years) coupled with a limited focus on cost control performance alone, renders their research less than adequate to meet current needs.

The issues described above combine to form the gap between the existing body of knowledge and that required to meet the needs of the current study. This lack of definitive school construction performance information impacts the decision-making of both state and district agencies in their quests to select the most appropriate methods of project delivery for their projects. Therefore, this study was focused on providing comparative performance data for public school projects constructed with both the Design-Bid-Build and CM at-Risk project delivery methods in order to assist decision makers in making the most appropriate project delivery choice.

Note that the term "public school(s)" utilized throughout this research refers only to publicly funded school(s), grades kindergarten through twelfth grade (K-12).

1.3 Research Questions

The purpose of this research was to provide current, statistically significant, empirical evidence defining the comparative performance attributes of the most widely utilized project delivery methods of Design-Bid-Build and CM at-Risk in the construction of public school projects. It is important to note that a preliminary study was conducted by the researcher in 2012 to determine whether Design-Build was among the project delivery methods commonly being utilized for construction of public schools within the study area of Florida, Georgia, North Carolina, and South Carolina. A review of the records available in each of these states indicated that, during the 7 year period targeted for this study (2006 to 2012), Design-Build was only utilized for construction of new, full facility, public schools in the states of Florida and North Carolina. Furthermore, only 1 of the almost 200 projects in North Carolina and only 15 of the more than 230 qualifying projects in Florida were completed utilizing the Design-Build method during this same period. Therefore, due to the limited utilization and thus, limited available project data representing the Design-Build project delivery method, this method was not included within the current research.

The performance attributes compared between the two project delivery methods were: cost, time, quality and claims (definitions of these terms will be provided in the following section). The research sought to answer the following questions:

1. How do public school projects in Florida, Georgia, North Carolina, and South Carolina constructed using the CM at-Risk project delivery method compare to those constructed using the Design-Bid-Build method utilizing the performance metrics of cost, time, and quality?

2. Is there a statistically significant difference in the number and severity (in terms of cost) of construction claims for public school projects constructed utilizing the CM at-Risk and Design-Bid-Build project delivery methods?

3. What criteria do school district administrators acting in the capacity of public owners utilize to make project delivery method selections?

Answers to these questions will provide critical information enabling public officials to enact legislation and execute policies encouraging utilization of the most appropriate project delivery methods, while empowering district construction managers and other decision makers to confidently make informed project delivery method selections, both of which will serve to benefit the public.

1.4 Research Significance

This project delivery performance research, data analysis, and findings provide the following significant benefits that will aid the public education system, the construction industry, and the public at large.

- *Benefit One* – The research results benefit government agencies and those in the position of structuring laws and regulations that govern the construction of public school projects. The results of this study will aid lawmakers in their efforts to craft and defend fair and rational policies and statutes that allow for utilization of the most appropriate project delivery methods for the construction of public schools. Furthermore, the findings of this research and the information provided in this report empower decision makers at the state and district level to make informed decisions regarding the selection of the most appropriate project delivery methods for their public school projects.

- *Benefit Two* –The research provides an opportunity for the public to benefit by obtaining public school facilities through the use of delivery methods that are more effective and cost efficient. Improved decision-making by district administrators will help provide public school facilities at the lowest reasonable cost while delivering these projects at the expected quality in a timely fashion. This will enable the public to conserve resources and shift concerns toward other efforts to improve public education.

- *Benefit Three* – Future construction research efforts will benefit from methods developed during this research. This study included the development and utilization of a historical construction project data collection mode to assemble and record project data. Research data were recorded directly from construction documents collected from the records of 137 public school projects. This is the first known independent, public school, construction performance research effort of this magnitude to utilize actual construction documents for the purposes of data collection and verification. This data collection method allowed for improved quality and accuracy of the data which increased the reliability and validity of the results obtained through analysis. This data collection method was an improvement over that utilized for the foundational work of Konchar (1997) and Konchar and Sanvido (1998) in which a survey data collection mode was utilized.

- *Benefit Four* – The development of the improved survey instrument from the foundational tool provided by Konchar (1997) will provide a useful survey model that can be modified and utilized by those in public education, the construction industry, and academia to continue to build on a project delivery method database. The survey instrument is designed to obtain reliable owner provided responses regarding their perceptions of project team performance on construction projects for which historical project data have previously been collected.

- *Benefit Five* – The research benefits the construction industry by providing conclusive comparative performance measures of the CM at-Risk and Design-Bid-

Build methods when utilized for the construction of public schools. The results are supported by a two year study of industry practices and robust statistical analysis that accurately reflects significant performance differences between these two methods. This information serves as a guide to the construction industry highlighting areas for which training and resources should be allocated, such as collaboration and communication skills, in order to improve construction service and project quality.

- *Benefit Six* - Additionally, it is recommended that training programs should be developed to educate district managers and other decision makers on the benefits and limitations of all project delivery methods, their proper situational utilization, and the levels of district construction manager experience and sophistication required for successful implementation and utilization.

1.5 Research Limitations

No research project is completed in a manner that is without limitations and this study will not be an exception. An initial limitation of the research is that results will be directly generalizable only to future projects within the defined sample, i.e., public school projects within the states of Florida, Georgia, North Carolina, and South Carolina, and not to a broader area or project type. Although similar results can be expected on projects of this type within this region, utilization of the research for projects that fall outside of the study region will require a close examination of the local factors influencing project performance and should include analysis utilizing local project data.

Note that random sampling approaches were considered for the selection of projects in both the historical data collection and the survey data collection steps in an effort to improve both validity and generalizability of the results. However, after careful consideration it was decided that data collection of the greatest possible volume from the largest number of projects, albeit not randomly collected, would be much more productive without sacrificing much of the validity and maintaining the characteristics of generalizability as put forth by Lee and Baskerville (2003).

It is acknowledged that the argument can be made that a properly conducted close comparison study comparing a very limited number of similar projects as conducted by Bender (2004) could yield results that are more precise or representative than a study making the comparison of a large number of projects within a narrow typology constructed across a wide variety of districts. However, the argument can also be made that research comparing only a few projects with controlled conditions, exacting standards, and precision instruments may not yield results that are representative of the same projects constructed even six months later in the same locations. This does not mean that the information obtained from that study would not be important, valid, or useful. It simply means that the information obtained would be most important, valid, and useful to the district in which the study was completed. However, due to the numerous variations that exist among projects and the districts in which they are constructed, there would be limited if any evidence to show that the results of the close comparison study would be generalizable to projects in other districts. Additionally, the usefulness of the results for the prediction of outcomes on future projects would be limited by the selection of only a small number of projects. The argument stems from the relative frequency concept of probability, in which it has been shown that analysis of a large number of similar events can yield results that allow for the increased probability of making accurate predictions of future outcomes for similar events (Ott, 2010). Furthermore, and probably the most convincing argument, the comparison of a few relatively identical projects would require that these projects were clearly defined, with complete construction documents, and were very unlikely to require changes or modifications. This closely meets the definition of a project well suited for Design-Bid-Build (Gordon, 1994); but, it is contradictory to key beneficial properties of alternative methods, such as constructability reviews during the design period and fast-tracking.

Taking these issues into consideration and acknowledging that alternative means and methods for obtaining data and conducting research do exist, the decision was made to conduct the study utilizing a methodology consistent with that of the foundational research of Konchar (1997) encompassing a relatively large number of projects and districts in order to provide important, valid, and useful information to a broader range of those involved with the construction of public schools.

Another limitation of this study is that the Design-Build method was not able to be included in the research due to the limited number of school projects completed with this method in the study area. Design-Build is acknowledged as being a viable and important alternative delivery method and the analysis of the performance of projects constructed utilizing this approach in future studies will be useful in obtaining an improved understanding of collaborative delivery methods.

Also, as will be thoroughly discussed in later sections, the data required for the stage one portion of the research is not collected in a uniform manner, nor is it maintained in a central repository within each state in the study area. For these reasons, data collection and comparison was dependent and limited to that maintained and accessible at the district level. Furthermore, the widespread locations of the individual districts inhibited the collection of project data from a larger number of districts due to the time constraints of the planned research.

It should also be mentioned that analysis of the survey responses revealed a few areas in which additional questions could have been asked that would have been useful in clarifying other areas of the research. For example, questions were not asked about the utilization of prototypical school project designs. Although a few district managers listed prototype utilization when given the opportunity to note "other issues," a direct question would have been useful in determining the extent of prototype utilization. Additionally, although the research accounted for the square foot area of the schools constructed within the study, the survey did not query the quality of materials and equipment, nor the types of space that were constructed. For example, the square foot area assessments did not differentiate between library, cafeteria, classroom, and computer lab spaces, all of which vary in cost of construction. Likewise, the survey did not include an examination of the project specifications or contract details in order to determine utilization of high performance mechanical, plumbing, and electrical equipment or the quality of interior and exterior finishes and building systems, which could have been utilized to explain differences in cost, value, and other performance measures.

And finally, although steps were taken to safeguard against it, it is possible that bias may have been recorded in either stage of the data collection process. For example, during stage one, a participant that had recently experienced low performance with one project delivery method or the other may have been resistant to providing access to historical project records. During stage two, it is possible that participants having strong positive beliefs about a particular project delivery method may have been more apt to complete surveys, while those that have negative perceptions may have been more reluctant. Additionally, those that had a difficult or negative experience during a recent project may have been more resistant to completing the survey instrument. For these reasons, it is possible that results obtained during the analysis phase may have been biased in favor of a particular project delivery method or other factor. Care was taken during the historical data collection stage to encourage wide participation by explaining the value of the research and the confidentiality of the information obtained. Care was also taken in the development and wording of the survey directions and questions to help encourage completion of the survey by all participants. Additionally, a concerted effort was made to obtain data from a large sample of projects constructed utilizing both types of project delivery methods in order to help reduce the influences of bias.

1.6 Chapter Summaries

Chapter Two provides an overview of alternative project delivery methods including the operational definitions and theoretical constructs utilized throughout the research. The chapter goes on to discuss developmental factors and utilization of alternative methods and closes with a review of the contrasting research perspectives.

Chapter Three examines the research constructs and provides a listing of the hypothesized relationships between the constructs and the comparative performance metrics of the projects included within this study.

Chapter Four explains the research design and methodology for this study. It includes definitions of the project variables and performance metrics along with an explanation of the sample design and data collection methods. A detailed description of the stage one historical data collection and the design and distribution of the survey instrument utilized in stage two of the process is included. A description of the pilot study is provided at the end of this chapter.

Chapter Five describes the research analysis and findings of the study. A detailed description of the testing procedures utilized for the comparative analysis of Design-Bid-Build and CM at-Risk performance metrics is provided. The results from each level of testing (by delivery method, by state, by type, and by state and type combined) are described. Theoretical implications of the results will be described in Chapter 6.

Chapter Six begins with a review of the impetus behind the study and a review of the research questions. The chapter will summarize the completed research and will draw conclusions from the empirical findings based on the theoretical implications discussed throughout the dissertation. The policy implications related to the results of the study will be discussed and a section describing recommendations for future research will follow. The final section summarizes the research and the significance of the findings.

CHAPTER 2:

ALTERNATIVE PROJECT DELIVERY METHODS

2.1 Operational Definitions

This section examines the varying definitions presented by subject matter experts and develops the precise definitions utilized for this research. It is important to note that differing opinions exist as to what constitutes the CM at-Risk project delivery method and its defining characteristics that specifically differentiate it from Design-Bid-Build and other delivery methods. A complete list of definitions is provided in the Glossary.

2.1.1 Project Delivery Method

Although, varying definitions exist within the construction industry, the following description will be utilized to define project delivery method within this research.

> *Project Delivery Method* – The comprehensive process of assigning contractual responsibilities for designing and constructing a project to include:

- Definition of the scope and requirements of a project
- Contractual requirements, obligations, and responsibilities of the parties
- Procedures, actions, and sequences of events
- Interrelationships among the participants
- Mechanisms for managing time, cost, safety, and quality
- Forms of agreement and documentation of activities (Kenig, 2011)

2.1.2 Design-Bid-Build

The Design-Bid-Build project delivery method was developed in the late 19th century following a number of fraud and abuse charges levied against contractors associated with large US infrastructure projects including the transcontinental railroad (US DOT, 2006; Heady, 2013). The process was designed to reduce risk in the areas of corruption and cost and can be utilized to produce quality results when employed in the proper circumstances for both public and private projects.

According to FMI, Design-Bid-Build is the most widely utilized and accepted project delivery method utilized throughout the United States for both private and public construction (FMI/CMAA, 2010). This method is known as the traditional method of project delivery. Design-Bid-Build is suitable for projects that are clearly defined and relatively unlikely to change, well designed with complete design documents, and that do not have greater than average schedule challenges (Gordon, 1994).

The structure of the Design-Bid-Build method is shown in Figure 2.1. The method follows a mostly linear process in which the architect is hired by the owner to help program and design the required facility prior to releasing the construction documents for competitive bidding (Civitello, 2000). A contract is then awarded by the owner to the lowest qualified bidder who then becomes the general contractor for the project. The general contractor then typically enters into subcontracts with specialty firms, generally known as subcontractors, who complete the majority of the work (Demkin & AIA, 2009). The defining characteristics of the Design-Bid-Build project delivery method are:

- Design and construction are separate contracts -- owner-designer, owner-contractor
- Total construction cost is a factor in the final selection of the constructor (AIA-AGC, 2011; Kenig, 2011).

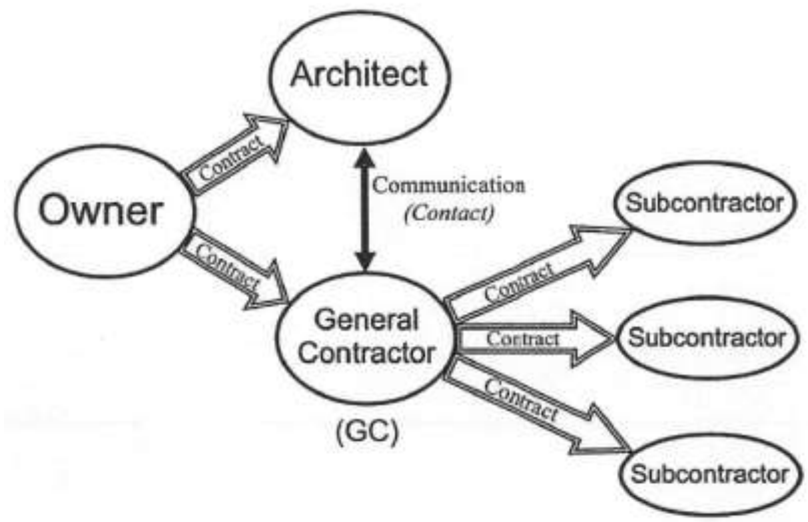


Figure 2.1 Design-Bid-Build
Contract Structure (Civitello, 2000)

It has been reported that the Design-Bid-Build project delivery method provides for an easily understood and well documented process, the perception of fairness, owner control of the process, and reduced issues of corruption as well as sound schedule predictability and *initial* cost certainty (Rojas & Kell, 2008; Kenig, 2011; US DOT, 2006). Disadvantages of this approach are reported to include: adversarial relationships brought on by the allocation of risks within the separate contracts, the competitive nature of the selection process driving prices to levels at or below the actual cost, construction documents and budgets that are prepared without the input of those that will ultimately construct the project, and the lack of flexibility to incorporate changes due to the linear process of design followed by construction (Konchar, 1997; O'Connor, 2009; US DOT, 2006; AIA-AGC, 2011; AIA & AIA California Council, 2007). (A matrix adapted from the AIA-AGC, (2011) listing known pros and cons related to the project delivery methods described in this proposal is provided in Appendix A.)

Each of the issues noted above increases the risk of reduced quality, schedule overruns, change orders, claims, and litigation. And, although the magnitude of the impact that these issues have on the *initial* project cost is unknown, the issues can lead to an increased *final* project cost that may exceed the owner's budget.

2.1.3 Construction Manager at-Risk

Proponents of alternative delivery methods, such as CM at-Risk, believe that these methods offer the promise of improved cost, time, and quality performance when the alternative methods are utilized on certain types of projects (Konchar & Sanvido, 1998; US DOT, 2006; AIA-AGC, 2011). The key differences that proponents say alternative methods offer center around integration of expertise and collaborative approaches that enhance performance throughout the entire design and construction process (Konchar, 1997; Kenig 2011).

As shown in Figure 2.2, similar to Design-Bid-Build, CM at-Risk maintains a two separate contracts approach; but what is not shown is the timing or method of selection (procurement). Defining characteristics of the CM at-Risk project delivery method are:

- Design and construction are separate contracts -- owner to architect, owner to CM at-Risk
- Total construction cost is not a factor in final selection of the constructor (AIA-AGC, 2011; Kenig, 2011).

Note that the substantial difference between CM at-Risk and Design-Bid-Build is the method of selection (procurement). The procurement of construction services utilizing a CM at-Risk is typically made on a qualifications-based, or qualifications and price (best value) selection early on in the process in lieu of competitive bidding after design and documentation of the project have been completed (Kenig, 2011).

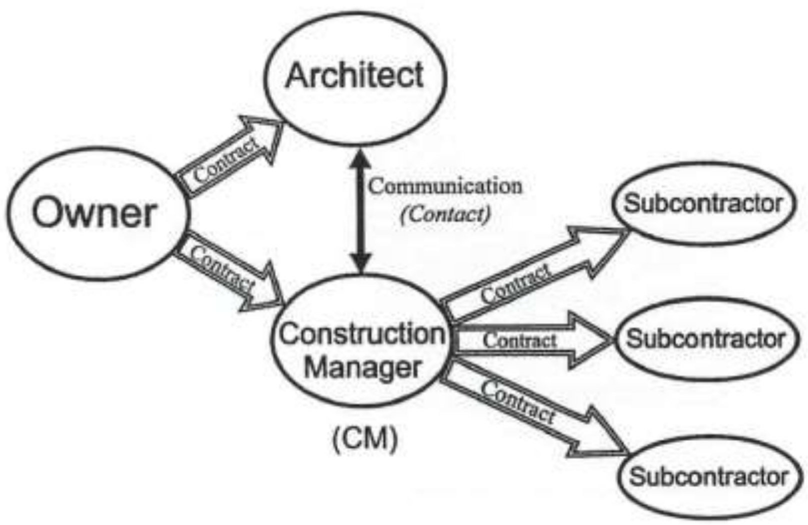


Figure 2.2 Construction Manager at-Risk (CM at-Risk) Contract Structure (Civitello, 2000)

Early selection allows the CM at-Risk an opportunity to provide input during the development of the construction documents and to provide constructability reviews and cost analyses during this period. Participation by the CM at-Risk at this stage of the project is expected to have a substantial impact on the entire project life cycle assisting the owner and architect in keeping the project within budget and on schedule.

The qualifications-based selection is expected to increase the opportunity of obtaining the best combination of performance, qualifications, and price while reducing the risk that an unqualified (albeit low price) contractor is selected. In turn, the quality of the project is said to improve and thus, reducing the potential for rework, cost and schedule overruns, change orders, and litigation (AGC-NASFA, 2006; US DOT, 2006). Additionally, proponents state that the collaborative establishment of an open-book Guaranteed Maximum Price (GMP) by the owner, architect, and contractor in lieu of a competitively bid lump sum reimbursement can provide a reduced risk, transparent environment for the project team which, should foster trust, leading to better project quality and reduced costs (Kenig, 2011).

And finally, another possible benefit of the CM at-Risk approach purported by its supporters is that it can reduce overall project time by reducing the linearity of the construction life cycle processes allowing the construction phase to start prior to the completion of final contract documents in the design phase. This process is known as fast-tracking (Ibid).

2.1.4 Design-Build

As was noted in Chapter 1, the Design-Build method was not the focus of this research due to a limited volume of project data. However, the operational definition of the Design-Build method has been provided due its significance in the development of alternative methods as a whole and due to the importance in presenting how the Design-Bid-Build and CM at-Risk methods are differentiated from it.

Proponents of Design-Build project delivery believe that this method provides many of the same benefits as the CM at-Risk method, even though it utilizes a different contractual relationship. The defining characteristics of the Design-Build project delivery method are:

- Design and construction responsibilities are contractually combined into a single contract -- owner to design-build entity" (AIA-AGC, 2011).

With the Design-Build approach, the contractor and architect operate as a combined, single entity and the owner maintains only one contract with that entity as shown in Figure 2.3 (Kenig, 2011). And, although selection can be made based solely on competitive bidding, Design-Build work is typically selected utilizing a qualifications-based or qualifications and price (best value) approach (Ibid). The idea is that the Design Build method provides the opportunity for the architect and contractor to work as a team from the outset allowing for more open, honest, and direct communications that can increase the opportunities for cost-reducing innovations.

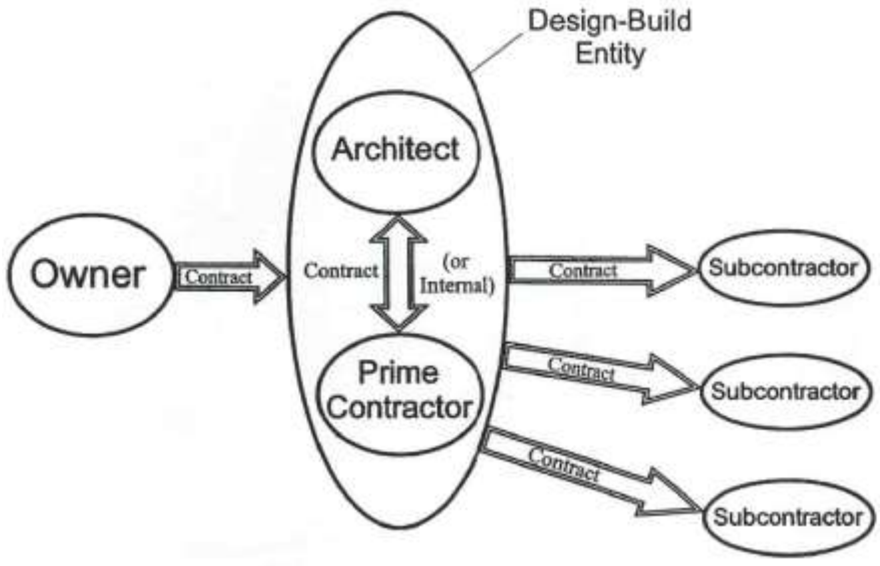


**Figure 2.3 Design-Build
Contract Structure (Civitello, 2000)**

Due to the overlapping of the design and construction phases, fast-tracking is reported by proponents of Design-Build as a major attribute of this method which, they say, can be extremely beneficial at reducing the project duration. And, similar to CM at-Risk, both lump sum and GMP reimbursement contracts can be utilized as deemed appropriate by the owner.

2.2 Developmental Factors of Alternative Methods

The following section describes many factors including fragmentation of the industry, risk, and interdisciplinary collaboration and communication that have contributed to the development of alternative delivery methods as a means to improve the construction process.

2.2.1 Fragmentation of the Industry

Other than caves and other naturally formed structures, it is theorized that early construction consisted of grass and mud huts designed and constructed by their inhabitants. Although little if any evidence remains of these primitive structures from ancient and medieval times, minimally advanced cultures in New Guinea have been seen utilizing this type of dwelling (Shand, 1954; Cowan, 1977). Advances in construction in ancient times centered on the growth of infrastructure for growing populations and cities. Prior to the Renaissance, most often a single person known as the master builder would complete the duties of both the architect and contractor in what was arguably the original form of the Design-Build project delivery method (Fitchen, 1986). The master builder would perform at the direction of the owner (Pharaohs, Kings and Queens, Emperors, or other rulers of the day) that generally held ultimate control over the required resources including capital, land, men, materials, and equipment.

Due to advances in technologies, specialization, increasing complexity of projects, and private development, the architect profession as we know it today was created in Italy during the Renaissance period (Addis, 2007). At about the same time, civil and military engineering schools were established in Paris and Prague (Addis, 2007; Songer & Molenaar, 1996). Thus began the fragmentation of the master builder into the formal disciplines of architecture, engineering, and construction ultimately leading to the present day construction industry.

It is important to note that the distinguishing factor between the era of the master builder and the multidisciplinary structure of the current construction industry is the distribution of power and control over the elements of the process including the design, construction, and the required capital resources. As a consequence of fragmentation, the disparate interests, commitments, perceptions, and understanding of the multiple entities now complicate the communication and decisions required (Forester, 1989) to design and build new structures which serves to increase risk among concerned parties. Alternative delivery methods seek to close the gaps created by fragmentation utilizing collaborative and communicative strategies.

2.2.2 Construction Risk

The construction industry is an inherently risky business due to many factors including the previously discussed fragmentation of the industry, complex relationships, the dynamic environment, and technological challenges (Saporita, 2006; Zaghloul & Hartman, 2003; Akintoye & MacLeod, 1997; Gordon, 1994; Kangari, 1995; Al-Bahar, 1990, McGraw-Hill, 2011). Additionally, history has shown that parties associated with construction projects have difficulty understanding and accepting responsibility for the risks associated with them (Kangari, 1987). Each of these issues has a direct impact on productivity, quality, and cost, which increases the difficulty of managing and constructing a successful construction project (Kangari, 1995; Zaghloul & Hartman, 2003; Al-Bahar, 1990).

According to Akintoye and MacLeod (1997), the risk threshold of those involved on construction projects is influenced by their personal and corporate beliefs, ideas, feelings, perceptions, experience, judgment, attitudes. Perry and Hayes (1985) describe construction risks as being related to physical, environmental, design, logistical, financial, legal, political, construction, and operational issues. The project owner has the responsibility of recognizing the risks involved for each project and selecting a strategy to either avoid, reduce, transfer, or retain and manage those risks (Ibid). In this regard, the owner must select a project delivery method early on in the process that he believes is best suited to manage, organize, and control the project risks. This selection encompasses the owner's beliefs regarding a broad array of issues including the contract obligations and responsibilities, the manner in which the scope of work will be designed and managed, and the interrelationships of the parties involved (Kenig, 2011). The selection of a specific construction contract form and the terms included therein solidifies the owner's beliefs regarding the transfer of risks and responsibilities among the various parties involved with the project.

Unfortunately, the contract clauses do not always allocate risk equitably and fairly among the project participants which, leads to delays and increased costs in the form of contingencies, claims, and disputes (Gordon, 1994; Kangari, 1995; Zaghloul & Hartman, 2003). Two independent studies conducted on projects across Canada confirm that the cost premium associated with the risk for exculpatory contract clauses alone ranges between 8 to 20% of the total contract cost (Zaghloul & Hartman, 2003). Additionally, unfair allocation of risk can lead to the destruction of trust creating a lack of cohesiveness and coordination, untimely decisions, and adversarial relationships (Zaghloul & Hartman, 2003; Akintoye & MacLeod, 1997; O'Connor, 2009).

Factors such as those described above continue to inspire those in the construction industry to look for new and different methods for dealing with problems issues and their associated risks. The utilization of alternative methods of project delivery is seen as a means of risk reduction by reducing the probability of problem issue occurrence (Akintoye & MacLeod, 1997).

2.2.3 Communication and Collaboration

The construction industry is mostly situated in the post-positivist philosophy of cause and effect, and utilizes the scientific method as the basis of many problem solving processes. Procedures developed for the construction industry such as project delivery methods, contracts, schedules, and budgetary processes must be well defined and understood by the project team in order for them to be effective (Saporita, 2006). As such, effective communication among the project participants is essential within these and other construction processes (Sanvido, Grobler, Parfitt, Guvenis, & Coyle, 1992; Pinto & Slevin, 1987; Chua, Kog, & Loh, 1999). However, as has been described, fragmentation of the construction industry has served to complicate communications and decision-making processes.

Innes and Booher (2010) describe similar issues of fragmentation, technology, communications, and political savvy that affect the planning field within the framework of Rittel and Webber's (1973) wicked problems. The wicked problems they describe often involve many diverse players with complex, interdependent relationships making the problems seemingly impossible to solve. While construction project issues do not typically rise to the level of complexity of wicked problems, solutions offered for dealing with them could be beneficial to the construction industry. Innes and Booher (2010) explain that traditional, post-positivist approaches do not provide solutions for these types of problems; and they suggest that collaborative methods are more suited to dealing with them. The key to the success of these collaborative methods is that, once trust and credibility are established, people feel more secure to lower their guard and to share ideas and concepts that help to solve problems and leads to risk reducing innovations (Kouzes & Posner, 2007). These ideas support the beliefs of alternative delivery method proponents.

However, these strategies are often in direct conflict with Western thought which typically utilizes a linear, scientific model based on instrumental rationality to solve problems (Innes & Booher, 2010), which may lead to a resistance toward alternative methods among traditionalists. Instrumental rationality employs the scientific approach to breakdown issues into their component parts where they are analyzed and “fixed” by experts implementing the optimal solution (Ibid). This model assumes that the experts know what is necessary (desired by the end user) and therefore, it is assumed that they can provide a satisfactory solution that will be controlled and measured utilizing performance variables (Ibid). Instrumental rationality and the scientific method are utilized throughout the construction industry, where dozens of processes, procedures, and methods have been and continue to be designed to address any given problem or issue. The industry depends on the traditional and scientific approach as a means to estimate quantities, record performance, manage personnel, and control construction projects and the risks associated with them utilizing the most productive, yet efficient, means and methods available. Unfortunately, complexity, perception, communications, and power issues can preclude decision makers from having complete or correct information with which to make optimal decisions (Forester, 1989).

"Practitioners and researchers from different design disciplines have recognized that concurrency of knowledge and interdisciplinary collaboration during the design process are fundamental conditions for the development of better products" (Cavieres, Gentry, Al-Hadad, 2011, p. 716). Proponents of alternative project delivery methods believe that early involvement of constructors during the design process will increase communication through project constructability reviews and thus, should lead to reduced costs by enabling the design team to make changes sooner (AIA/HOK, 2004; Paulson, 1976). As is shown in the MacLeamy Curve in Figure 2.4, the cost impact of design changes (2) rises as the project development cycle matures, while the level of ability (1) design changes have to impact project cost falls.

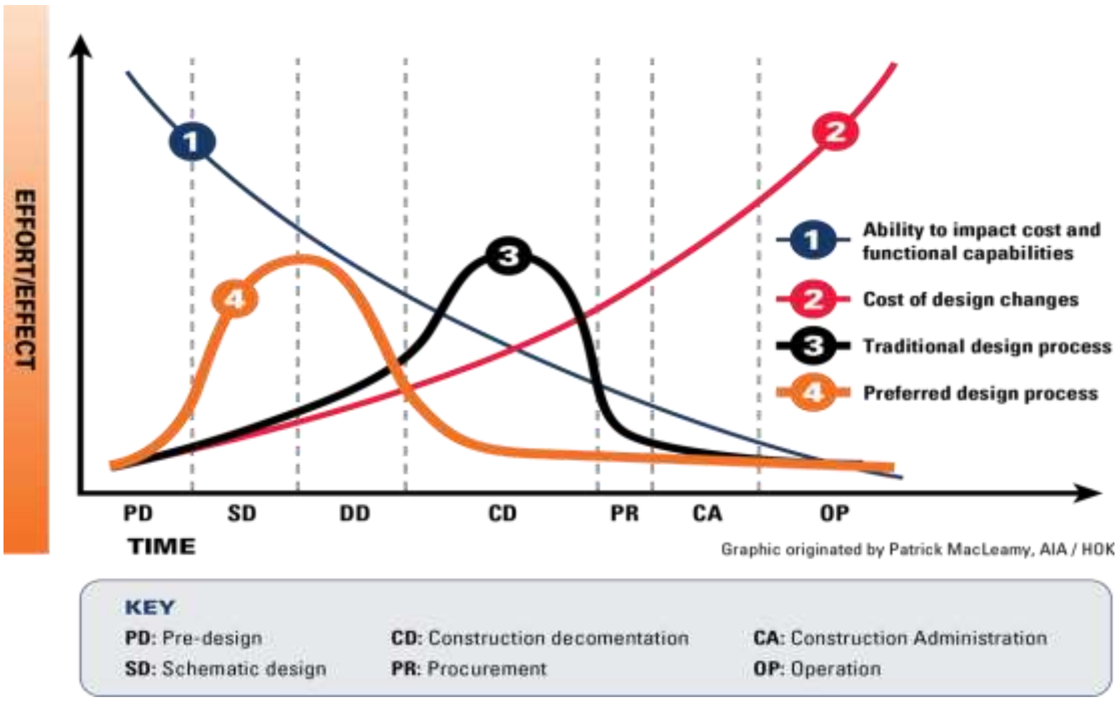


Figure 2.4 MacLeamy Curve (AIA/HOK, 2004; Paulson, 1976)

The MacLeamy Curve supports the call for early and open communication and collaboration in order to promote efficient construction productivity, implying that changes should be made early on during the project life cycle in order to have the greatest influence at the lowest cost.

2.2.4 Project Success Factors

There have been continual efforts to provide a universal definition for construction project success. It is doubtless that project success has been considered by researchers and others prior to the modern age, but the first mention of Critical Success Factors (CSFs) comes from research conducted in the area of information systems by

Rockart (1979) at Massachusetts Institute of Technology (MIT). The definition of CSFs was later refined and presented by Bullen and Rockart (1981) as:

> the limited number of areas in which satisfactory results will ensure successful competitive performance for the individual, department, or organization. CSFs are the few key areas where 'things must go right' for the business to flourish and for the manager's goals to be attained (Ibid).

From 1990 to 2000, a documented 20 separate studies listed factors in 17 different categories in an effort to capture the essence of success related to the construction project (Chan, Scott, & Lam, 2002). Although various other factors do surface including safety, productivity, and others as shown in the Chan, Scott, & Chan (2004) diagram in Figure 2.5, cost, schedule, and quality are almost always listed as the primary indicators of project performance and are referred to as the iron triangle of success (Atkinson 1999; Chan, Scott, & Lam, 2002).

In an effort to define the effectiveness of Design-Build, the US Department of Transportation utilized criteria gathered from the research of Bennett et al. (1996), Gransberg and Buitrago (2002), and Konchar and Sanvido (1998) to develop a primary list of alternative delivery method performance measures. The categories and factors determined were: Cost - Unit Cost and Potential Cost; Schedule - Construction Speed, Delivery Speed, and Potential Schedule Growth; and Quality – User Satisfaction, Conformance to Specifications, and Conformance to Expectations (US DOT, 2006). And although, "no single list will ever be totally comprehensive when it comes to a definition

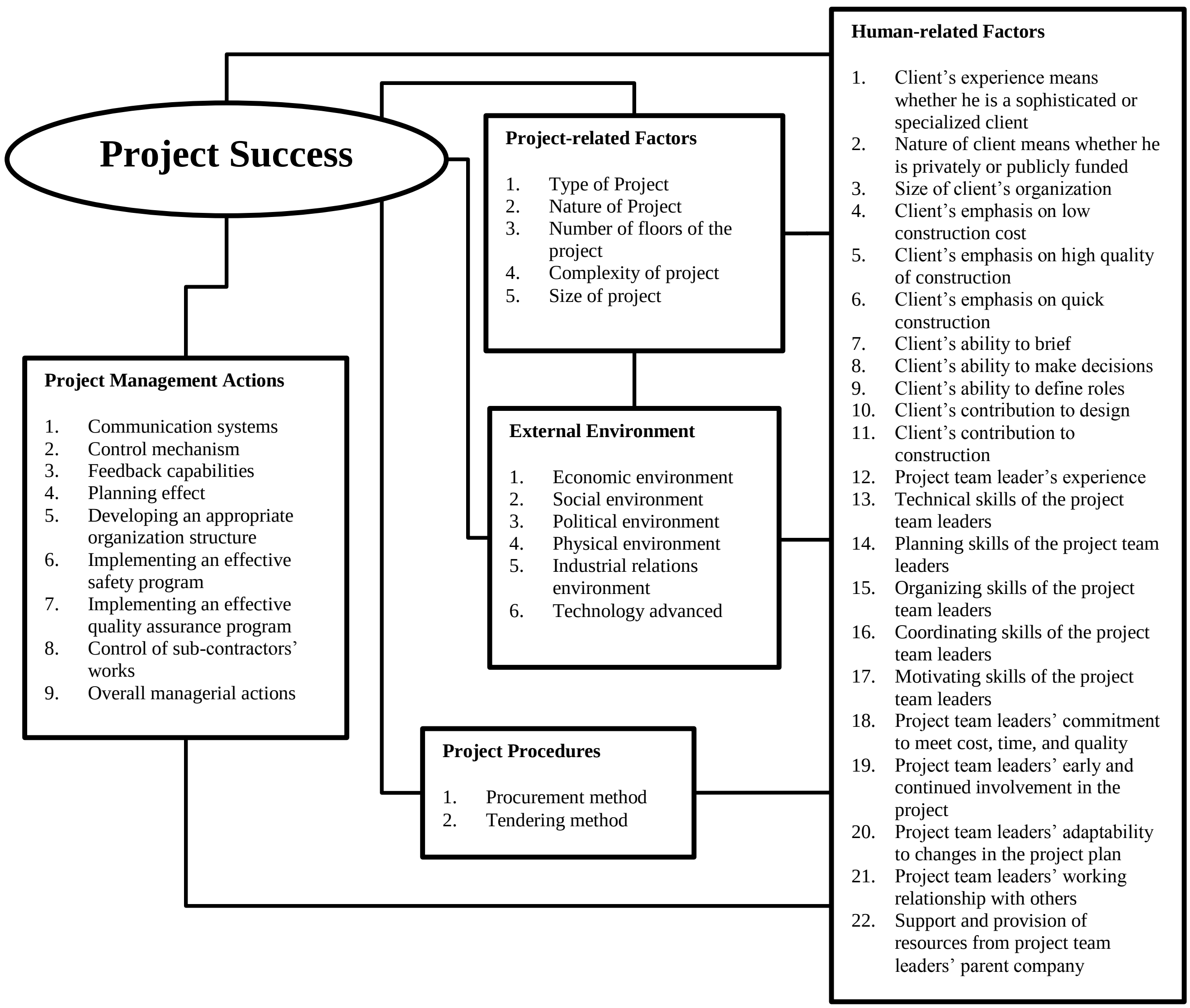


Figure 2.5 Factors Affecting the Success of a Construction Project (Chan, Scott, & Chan, 2004)

of success for a project" (Sanvido et al., 1992, p. 97), the literature reveals that the performance indicators for construction project success are generally based on measures of project cost, schedule, and quality (Sanvido et al., 1992; Chua et al., 1999; Atkinson, 1999; Kangari, 1995; Akintoye & MacLeod, 1997; Gordon, 1994; Konchar, 1997;

Saporita, 2006; Chan, Scott, & Lam, 2002; Konchar & Sanvido, 1998; Pinto & Slevin, 1987; Songer, Molenaar, & Robinson, 1997).

It is important to note that cost and schedule are often seen as objective measures; whereas, quality is seen as more subjective or intangible and thus, less measurable, as is shown in Figure 2.6 (Chan & Chan, 2004). Client satisfaction is also shown to be a subjective performance indicator and is an obvious target of focus during the construction process. Additionally, it is recognized that performance indicators can be and are influenced by management actions, project procedures, human relations factors, external environment factors, and project specific factors (Chan, Scott, & Chan, 2004). The premise behind the differing project delivery methods is that each of them offers different methods for dealing with these factors in an effort to improve project performance. For example, CM at-Risk provides an opportunity to reduce construction time (objective measure) by changing the linearity of the project life cycle. Additionally, client satisfaction (subjective measure) may be improved by a perceived increase in cooperation and communication instilled by the collaborative properties of alternative methods.

The research challenge is in formulating metrics that properly assess levels of performance as well as survey questions that properly reveal participant viewpoints toward these subjective issues when client satisfaction can be defined: to "minimize aggravation in producing a building" (Sanvido et al., 1992). Meeting this challenge has been an important element of the research and care has been taken to ensure that separate metrics and targeted questions were established in an effort to capture the true measures of performance while reducing variations due purely to subjectivity.

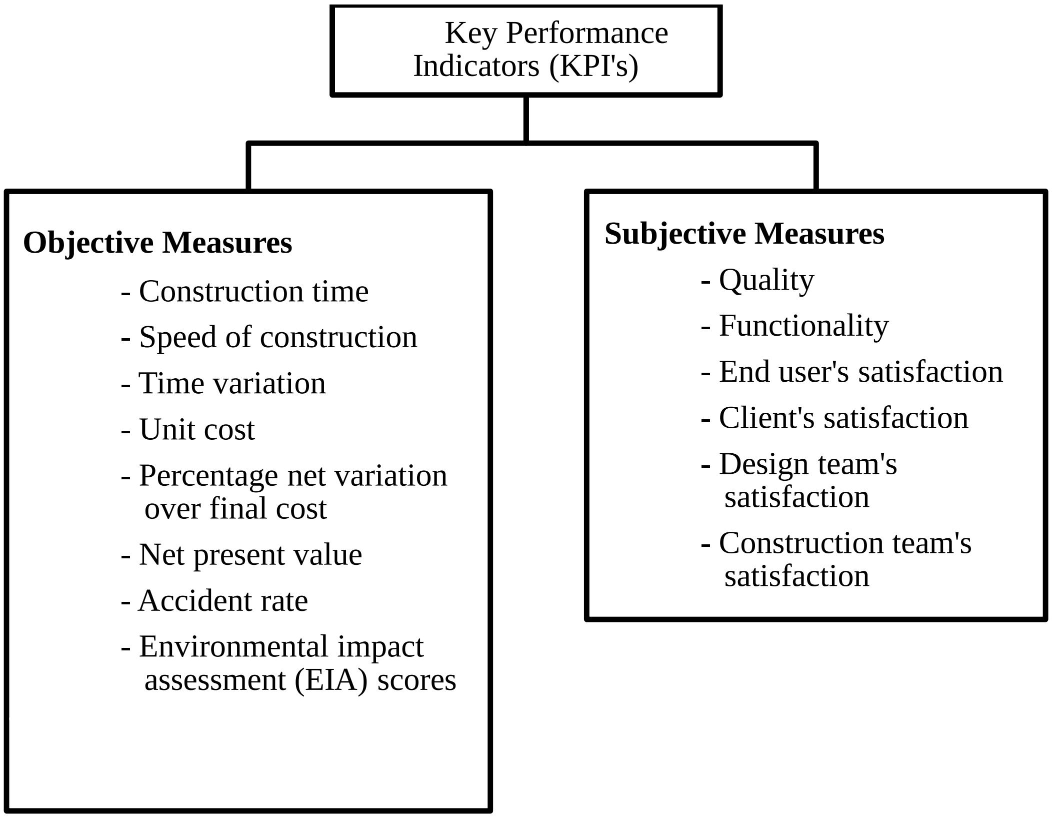


Figure 2.6 Key Performance Indicators (Factors) for Project Success (Chan & Chan, 2004)

2.2.5 Cost vs. Value

Before leaving the sections on performance factors, it is important to note the difference between cost savings and added value. Throughout the literature, researchers have utilized cost as a performance factor in terms of a purely mathematical measure. Projects that cost less are deemed to be delivered at a higher (better) performance level, while those that cost more are deemed to perform at a lower level (worse). However, as defined by Alarcon and Ashley (1996):

> *Cost*: Evaluates the total project cost included in an engineering-procurement-construction (E-P-C) contract, from engineering to the plant start-up.

> *Value*: Evaluates the satisfaction of owner's needs in a global sense. It includes the realization for the owner of quantity produced, operational and maintenance costs, and flexibility. This outcome measure might also be considered as the "business benefit" derived from the completed project (Alarcon & Ashley, 1996, p. 267).

Zeithaml (1988, p. 14) defines *Perceived Value:* "the consumer's overall assessment of the utility of a product based on perceptions of what is received and what is given."

In today's market, terms such as Lean, BIM, LEED, sustainability, and others promote the utilization of high performance designs, equipment, and materials for the construction of new facilities. While these innovative materials and processes may cost more in terms of initial construction cost, they are expected to assist owners in obtaining facilities that operate more efficiently in terms of cost, environmental, or other issues and thus, provide a better *value* in terms of life cycle costs. Some owners employing these methods and materials may find that the long term benefits outweigh the added initial cost and therefore, the higher cost may actually be an indicator of higher (better) project performance when measured in terms of added *value*.

As shall be discussed later in the Project Variables and Performance Metrics section, this research was focused on determining the project performance levels of actual design and construction costs. Research involving the issues and costs related to project operations or other life cycle issues and the determination of the owner perceived value levels for the materials and equipment utilized for these projects were beyond the scope of the current study.

2.3 Utilization of Alternative Delivery Methods

2.3.1 Advent of Alternative Methods

Beginning in the later part of the 19th century and proceeding through the first half of the 20th century, private developers grew to realize that architectural firms alone were not capable of delivering on their artistic visions for new high-rise buildings (Addis, 2007). During this period design firms such as Adler & Sullivan, Burnham & Root, and Holabird & Roche came into prominence due to their combined architectural, engineering, and construction expertise (Ibid) in what were the beginnings of the modern-day Design-Build and CM at-Risk methods. These firms and the developers that utilized them had learned the value of collaboration and communication when cost and schedule were important factors in the construction of their projects (Ibid).

2.3.2 Introduction into the Public Sector

Prior to the 1960s's, construction of public projects was to be procured only through utilization of the Design-Bid-Build approach (Ghavamifar & Touran, 2008). However, during the 1960's, the Defense Department and other federal agencies that were experiencing the need to expedite public projects and stretch resources began experimenting on a limited basis with alternative methods that had previously been gaining popularity in the private sector. Changes in federal regulations throughout the second half of the 20th century culminated in the Federal Acquisition Reform Act of 1996 (renamed the Clinger-Cohen Act) which paved the way for growth and widespread utilization of alternative methods within the public sector (Molenaar, Songer, & Barash, 1999). This legislation provided the legal authority that allows federal procurement of capital projects by means other than, or in addition to the Design-Bid-Build method.

Federal agencies including the Department of Defense, Veterans Administration, Department of Transportation, and many others regularly utilize alternative methods including CM at-Risk. Following the lead of the federal government, a 2003 report prepared by McGraw-Hill noted that 46 states allowed some form of alternative method of project delivery other than Design-Bid-Build for public projects. Currently, CM at-Risk is legally authorized at the state level for the construction of horizontal (highway, bridge, and tunnel) projects in 26 states, CM at-Risk is precluded in 14 states, and the law regarding CM at-Risk is not clearly defined in 10 states (AGC, 2012). For vertical (building) construction, CM at-Risk is legally authorized at the state level in 45 states, utilization is precluded in 1 state (Indiana), and the law is not clearly defined in the other 4 states (AGC, 2012).

Georgia and Florida were two of the first states to allow CM at-Risk for the construction of public schools after enactment of the Clinger-Cohen Act (Smith, 2001; Leavitt & McIlwee, 2011). North Carolina approved utilization of CM at-Risk in 2001 with the passage of Senate Bill 914. The 2008 Procurement Code Revisions – S. 282 fully authorized utilization of alternative methods in South Carolina in that same year (McCook, 2008). Furthermore, Article 9 Section 3005 of the South Carolina Model School District Code, effective August 15, 2011 authorizes the procurement of CM at-Risk, Design-Build, and other alternative delivery methods for construction of infrastructure facilities.

Despite gaining legal authorization, Ghavamifar and Touran (2008) suggest that fear of favoritism, unnecessary added costs, lack of experience with the processes, and loss of owner control may be influencing public decisions to adopt or utilize alternative methods of project delivery. Their research indicates that, although utilization has been authorized for federal Department of Transportation projects, many states have yet to fully authorize utilization at the state level (Ghavamifar & Touran, 2008). Additionally, anecdotal evidence suggests that public employees, acting in the positions of facility owners and managers, may still often be reluctant to utilize alternative delivery methods due to their lack of knowledge and experience or due to traditional operating procedures currently in effect (Carolinas AGC, 2009).

2.3.3 Growth in the Public and Private Sectors

Regardless of possible reluctance, utilization of alternative delivery methods is growing, with particular emphasis in the private sector, and small advances have been made in the public sector as well. In 2005 industry reports indicated that 66% of owners most frequently utilized Design-Bid-Build methods, while only 19% utilized CM at-Risk most frequently, and approximately 8% utilized Design-Build (FMI/CMAA, 2005). In later reports, FMI indicated that owner utilization of Design-Bid-Build had declined to 55%, while utilization of CM at-Risk (blended approach) and Design-Build had increased to 24% and 16% respectively as shown in Figure 2.7 (FMI/CMAA, 2007, 2010). During this same period, the report revealed that state and municipal utilization of alternative methods showed a slight increase, a possible indicator that legislative changes allowing for utilization of alternative methods may have had a positive effect.

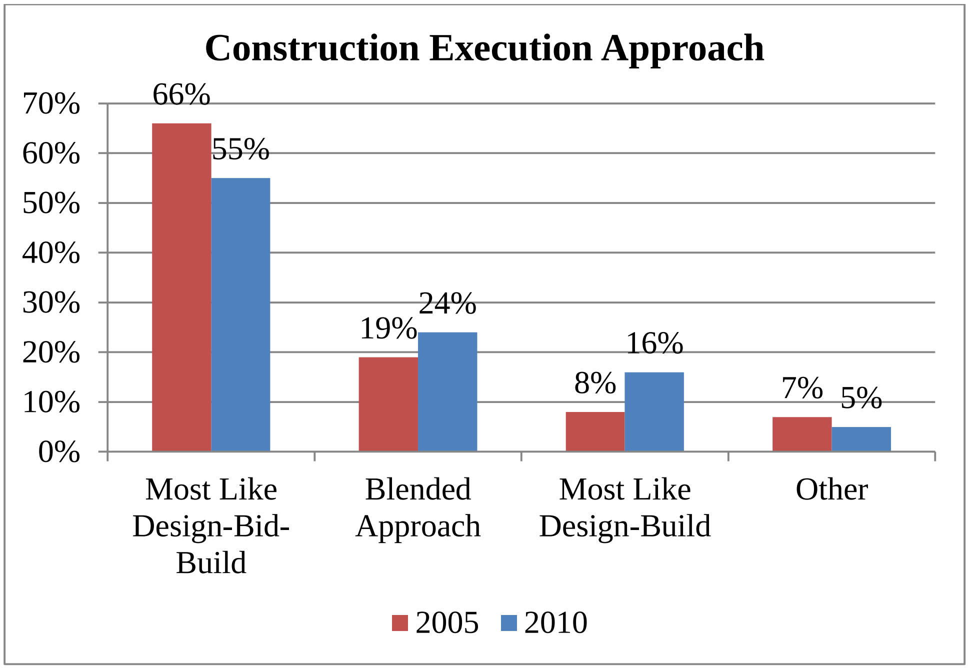


Figure 2.7 Construction Execution Approach (Method)
(Adapted from FMI/CMAA, 2005, 2010)

Also of note in the FMI reports, from 2007 to 2010 there was an increase in the utilization of the Design-Bid-Build project delivery method among both publicly held and privately held corporations, which was reportedly due to the economic conditions during that period (FMI/CMAA, 2010). Given that these types of firms are typically responsible for raising or utilizing their own capital, the subtle changes may indicate that the levels of risk associated with alternative methods shifts with various economic levels. However, a 2009 paper published by the National Association of State Facilities

Administrators (NASFA), argued that the economic conditions of that period do not assuage the benefits of alternative methods (Lynch, 2009). The paper encourages owners to stay the course toward utilization of alternative methods and argues the questions:

- What are the responsible actions to be taking in the current market?
- How do we ensure that we take advantage of the lower prices now available?
- Do we have to throw out schedule acceleration and collaboration to get the benefit of lower prices?
- How do we ensure an increased focus on price does not distract us from our goal of maximizing value?
- Which procurement type should we use?
- Should we be low-bidding everything? (Lynch, 2009, p. 1)

While these questions cannot be answered in isolation or by research alone, it is certain that none of them can be answered with confidence or that a consensus following can be established absent current, relevant, and significant empirical evidence.

2.4 Foundational Research

2.4.1 Bennett, Pothecary, & Robinson, 1996

The most widely cited previous research regarding the impact of alternative methods of project delivery refers to two similar studies that were completed more than a decade ago. The first of which, *Designing and Building a World-Class Industry* (Bennett, Pothecary, & Robinson, 1996), focused primarily on the comparison of Design-

Bid-Build and Design-Build approaches with analysis of cost, schedule, and quality data from various projects recently constructed across the UK. The researchers utilized surveys and interviews to collect and then analyze data on 332 projects. Their findings indicated that utilization of a Design-Build approach in lieu of Design-Bid-Build led to a 30% reduction in overall project duration (design and construction), a 12% reduction in construction duration, and a 13% reduction in cost per square meter (Bennett, et al., 1996). The researchers established benchmarks whereby the UK industry could build a foundation of continuous improvement in advancing the utilization of the Design-Build industry. The study has been criticized based on statistical imperfections and the limited usage of multivariate analysis (Konchar, 1997). However, this study was useful in establishing data collection methods and procedures that have been utilized in future studies to specifically target project performance in areas of cost, schedule, and quality.

2.4.2 Konchar, 1997

During the same period that the Bennett et al. (1996) research was being conducted in the UK, Konchar performed a separate but similar study in which he empirically compared performance of cost, schedule, and quality performance on 351 various projects across the United States (Konchar, 1997). Following his initial analysis, Konchar identified that empirical evidence was required in order to allow those involved with project planning to make well-informed and proper decisions. Konchar's focus was in developing a complete data collection and measurement system, measuring performance based on the system, and then predicting which characteristics had the greatest effect on project performance (Konchar, 1997). The study utilized univariate and multivariate statistical analysis of cost and schedule data and univariate analysis of quality data to compare nearly 100 variables related to the various project delivery methods (Konchar, 1997). As shown in Table 2.1, the univariate analysis conducted by Konchar determined that the performance of projects constructed utilizing the CM at-Risk project delivery method exceeded the performance of those constructed utilizing Design-Bid-Build in

Table 2.1 - Univariate Results from Konchar (1997) Research

Metric	Unit	CM at-Risk	Design-Bid-Build	Difference	p-value
Unit Cost	Dollars/SF	147.9	179.5	-17.6%	> 0.05*
Cost Growth	%	5.537	8.11	-2.57%	0.029
Schedule Growth	%	2.81	9.33	-6.52%	0.008
Construction Speed	SF/month	12910	9763	32.2%	0.054
Delivery Speed	SF/month	9017	6390	41.1%	0.0039
Intensity	(dollars/SF)/month	7.35	7.46	-1.5%	> 0.05*
Start-up	Survey response	7.434	5.963	24.7%	0.003
Callbacks	Survey response	8.067	7.037	14.6%	0.007
Operations & Maintenance	Survey response	6.69	6.881	-2.8%	0.017
Exterior & Structural	Survey response	5.357	4.952	8.2%	0.09
Interior & Layout	Survey response	6.284	5.185	21.2%	0.002
Environmental Systems	Survey response	5.338	4.858	9.9%	0.079
Equipment & Layout	Survey response	5.625	5.07	10.9%	0.08
* p-value not provided			(Konchar, 1997, Appendix B)		

almost all areas tested. This was the first empirical analysis completed within a large-scale research project comparing alternative delivery methods of projects in the United States (Konchar, 1997).

Findings of the study have been challenged by Williams (2003) based on the wide variations of the projects being compared in the areas of overall cost, square foot size, and complexity. Furthermore, it must be noted that analysis conducted by Konchar (1997) utilized the median values of the datasets in lieu of the statistically valid procedures in which the mean values are utilized. Still, the study remains the benchmark for alternative project delivery research.

2.4.3 Sanvido and Konchar, 1999

The Konchar (1997) study and the Konchar and Sanvido (1998) research were refined and utilized as the basis for the book, *Selecting Project Delivery Systems: Comparing Design-Build, Design-Bid-Build, and Construction Management at Risk* (Sanvido & Konchar, 1999). The book is presented as a guide to assist project owners in understanding and managing the selection process for their future projects. In 2001 the Construction Industry Institute (CII) published the *Owner's Tool for Project Delivery and Contract Strategy Selection User's Guide*, which included the *Project Delivery System Selection Workbook*, both of which were coauthored by Sanvido and Konchar. Furthermore, results of the original Konchar (1997) study and the later book have been utilized for widespread promotion of Design-Build by the Design-Build Institute of America. Williams (2003) questioned the statistical significance of some portions of the

Konchar and Sanvido (1998) research as well as the overall comparisons on construction and delivery speed (Rojas & Kell, 2008).

Sanvido & Konchar (1999) forecasted that the results of their research might change over time and went on to state, "It would be important to see whether project delivery systems and behavior change in the subsequent ten to twenty years" (Sanvido & Konchar, 1999, p. 20). The current research will examine the ways in which alternative methods are being utilized today for the design and construction of public schools.

Table 2.2 – Partial Results of Sanvido and Konchar (1999) Research

Metric	CM at-Risk vs. Design-Bid-Build	Level of Certainty
Unit Cost	1.6% lower	99%
Cost Growth	7.8% more	24%
Schedule Growth	9.2% less	24%
Construction Speed	5.8% faster	89%
Delivery Speed	13.3% faster	88%
(Sanvido & Konchar, 1999)		

2.4.4 Supporting Research

A study conducted by the Infrastructure Systems Development Research team at MIT (Miller, Garvin, Ibbs, & Mahoney, 2000) described the paradigm shift of the construction industry toward alternative delivery methods supported the view of the industry as described by Konchar and Sanvido (1998). Within the paper, the authors describe the existing paradigm of the Design-Bid-Build method and how it is ill equipped to handle current issues related to financing, fast-tracking, and innovation among others. They blame “mismatched project characteristics and procurement strategies (that) reduce life cycle value and innovation and allocate risks unfavorably” (Miller, Garvin, Ibbs, & Mahoney, 2000, p. 66). The authors of the study project that the paradigm shift will drive government agencies toward the adoption of policies to support the new methods. This is supported by the previously discussed Bennett et al. (1996) and NRC (2009) report.

Bender (2004) conducted research comparing the delivery methods utilized on two similar construction projects. The researcher’s conclusions confirm 2 relevant characteristic requirements for good project delivery selection that were described by Sanvido and Konchar (1999), the need for high levels of owner sophistication and experience, and the need for early definition of project schedule requirements.

2.4.5 Conflicting Research

Research conducted in the Pacific Northwest studied the performance of the CM at-Risk project delivery method when utilized on public school projects. The study, conducted by Rojas and Kell (2008), looked at 297 school projects and obtained results that contradict some of the claims of CM at-Risk proponents. The focus of the study was to determine whether CM at-Risk was better at controlling costs when compared to Design-Bid-Build (Rojas & Kell, 2008). Although much of the analysis did not result in statistically significant results, observable evidence was obtained. The analysis of cost control revealed that CM at-Risk did not outperform Design-Bid-Build; however, only 8% (24) of the total projects in the study were CM at-Risk. Additionally, the project data varied from 1 to 20 years in age and this could be seen as problematic when compared to projects being constructed with present technology in current conditions. The study is significant to the current research in that it validates the need for the empirical evidence at the public procurement level. Furthermore, examination of the study limitations assists the current research in developing methodologies that will improve statistical analysis and significance of results.

The Williams (2003) research study compared the performance of Design-Bid-Build and CM/GC (CM at-Risk) methods analyzing 215 publicly funded projects in Oregon. In addition to identifying possible issues related to the Konchar and Sanvido (1998) study, Williams (2003) concluded that there is no statistically significant difference between the CM at-Risk and Design-Bid-Build project delivery methods in regard to cost and schedule control (Williams, 2003). The study concluded that the CM at-Risk project delivery method actually had a higher per square foot cost and may not provide the reduced risk touted by its supporters (Ibid). However, the study did indicate that CM at-Risk may be a superior delivery method when dealing with projects that require accelerated (fast-track) project schedules. The Williams (2003) study is useful to the current research in that it identifies evidence of conflicting information with the benchmark Konchar and Sanvido (1998) study. This inconsistency in results serves to instill doubt within decision makers, which may contribute to their hesitation and lack of understanding of alternative delivery methods.

Ling, Chan, Chong, & Ee (2004) were also critical of the Konchar and Sanvido (1998) study stating, “regression equations, coefficients of variables, and R^2 were not reported in detail, thus limiting the usefulness of the models" (Ling et al., 2004, p. 76). This research is of value to the current study based on its emphasis on significant statistical analysis and the compilation of more than 50 potentially useful project performance factors (Ling et al., 2004).

Australian empirical research conducted by Love (2002) studied the effects that incidents of rework for defective and non-conforming work can have on the cost and schedule growth of various types of projects and project delivery methods. As has previously been stated, alternative project delivery methods offer the promise of reducing schedule durations by overlapping the design and construction phases. Fast-tracking in turn, can sometimes lead to changes, disruptions, and costly rework due to the fact that construction is started prior to the completion of the final drawings and specifications. Love (2002) utilized a survey instrument to collect data on 161 projects and found that there were no statistically significant differences between the rework costs and schedules of projects completed utilizing alternative delivery methods (Love, 2002). This implies that rework and schedule performance on CM at-Risk projects should be similar to (no better or worse) than Design-Bid-Build.

2.5 Summary

The literature review was useful in focusing the efforts of the current study on factors that construction industry professionals consider most relevant and important. Overall, the literature review provided a foundation of knowledge regarding alternative methods of project delivery in relation to the Design-Bid-Build method on which the current research will be constructed. That the construction industry is a complex and risky business environment comprised of fragmented agencies with diverse perspectives there can be no doubt. In order to provide for positive changes that achieve increases in productivity and efficiency within the industry, there is evidence to show that methods that improve communication and collaboration among the project participants should be adopted.

The current study examined the capabilities of the CM at-Risk project delivery method in an effort to discover whether this method provided performance improvements beyond those of the Design-Bid-Build method in the construction of public schools. The existing body of knowledge serves as both a scientific benchmark and historical reference of the work completed by committed scholars in order to advance the study of construction project delivery methods. The current research effort was designed to meet the standards set by those researchers.

CHAPTER 3:

RESEARCH CONSTRUCTS AND HYPOTHESES

3.1 Introduction

The purpose of this study was to provide current, statistically significant, empirical evidence defining the comparative performance attributes of the most widely utilized project delivery methods of Design-Bid-Build and CM at-Risk in the construction of public school projects.

Konchar and Sanvido (1998) completed the most widely cited and accepted research on the performance of alternative delivery methods for construction. However, the research of Rojas and Kell (2008) and Williams (2003) have called the Konchar and Sanvido (1998) research into question providing evidence of conflicting results and criticizing the statistical validity of some portions of their work. Williams (2003) and Rojas and Kell (2008) utilized projects exclusively from the northwestern US, which may serve to differentiate them from the projects within southeastern region under study. Furthermore, the Rojas and Kell (2008) research focused solely on cost control performance.

The research focused on an examination of the performance metrics of projects that were specific in size, type, and location in order to conduct the required level of analysis that would provide the statistically significant, empirical evidence needed to meet the purpose of this study.

3.2 Research Hypotheses

In order to test the purported benefits of the CM at-Risk project delivery method when utilized for the construction of public schools and to provide the current statistically significant empirical evidence required for this research, the following hypotheses have been developed. The performance indicators and metrics listed within these hypotheses will be discussed in detail in the following chapter.

The literature reveals that the performance indicators for construction project success are generally based on measures of project cost, schedule, and quality (Pinto & Slevin, 1987; Sanvido et al., 1992; Gordon, 1994; Kangari, 1995; Konchar, 1997; Konchar & Sanvido, 1998; Akintoye & MacLeod, 1997; Songer, Molenaar, & Robinson, 1997; Chua et al., 1999; Atkinson, 1999; Chan, Scott, & Lam, 2002; Saporita, 2006). Additionally, since construction claims are often the product of many factors including problems with communication and project documents, relationships, productivity, and workmanship and often lead to increased costs and schedule overruns (Saporita, 2006; Akintoye & MacLeod, 1997; Gordon, 1994; Kangari, 1995), construction claims can be utilized as an indicator of overall quality performance. Therefore, the hypotheses that follow have been structured to test the performance of the subject projects in terms of cost, time, quality, and claims.

Additionally, the null hypotheses designed to test each of these performance variables was based on the neutral position: there *is no statistically significant difference* in the level of performance for the metric being compared between the two methods (CM at-Risk or Design-Bid-Build). Conversely, the alternative hypothesis was based on the premise: there *is a statistically significant difference* in the level of performance for the metric being compared between the two methods (CM at-Risk and Design-Bid-Build). Note that there is no prediction as to whether the difference will be positive or negative and thus, a two-tailed test will be utilized.

3.2.1 Cost Performance Hypotheses

- Hypothesis 1: There is no statistically significant difference in the cost of public school construction projects completed utilizing the CM at-Risk method when compared to those completed utilizing the Design-Bid-Build method.
  - The cost metrics tested were: Original Construction Cost, Original Project Cost, Final Construction Cost, Final Project Cost, Construction Cost Growth, and Project Cost Growth.

- Hypothesis 2: There is no statistically significant difference in the unit cost of public school construction projects completed utilizing the CM at-Risk method when compared to those completed utilizing the Design-Bid-Build method.
  - The cost metrics tested were: Construction Square Foot Cost, Project Square Foot Cost, Construction Student Cost, and Project Student Cost.

- Hypothesis 3: There is no statistically significant difference in the cost growth of public school construction projects completed utilizing the CM at-Risk method when compared to those completed utilizing the Design-Bid-Build method.
    - The cost metrics tested were: Construction Cost Growth, and Project Cost Growth.

3.2.2 Schedule Performance Hypotheses

- Hypothesis 4: There is no statistically significant difference in the schedule duration of public school construction projects completed utilizing the CM at-Risk method when compared to those completed utilizing the Design-Bid-Build method.
    - The time metrics tested were: Planned Construction Schedule, Actual Construction Schedule, Planned Project Schedule, and Actual Project Schedule.

- Hypothesis 5: There is no statistically significant difference in the schedule growth of public school construction projects completed utilizing the CM at-Risk method when compared to those completed utilizing the Design-Bid-Build method.
    - The time metrics tested were: Construction Schedule Growth, Project Schedule Growth.

- Hypothesis 6: There are is no statistically significant difference in the intensity of public school construction projects completed utilizing the CM at-Risk method when compared to those completed utilizing Design-Bid-Build.
    - The time metrics tested were: Project Intensity Square Foot/Day, Project Intensity $/Day.

3.2.3 Quality Performance Hypotheses

- Hypothesis 7: There is no statistically significant difference in the product quality of public school construction projects completed utilizing the CM at-Risk method when compared to those completed utilizing Design-Bid-Build.
    - All survey responses related to product quality were tested.

- Hypothesis 8: There is no statistically significant difference in the service quality on public school construction projects completed utilizing the CM at-Risk method when compared to those completed utilizing Design-Bid-Build.
    - All survey responses related to service quality were tested.

- Hypothesis 9: There is no statistically significant difference regarding claims on public school construction projects completed utilizing the CM at-Risk method when compared to those completed utilizing Design-Bid-Build.
    - Survey responses to the number of claims and cost of claims questions were tested.

- Hypothesis 10: There is no statistically significant difference regarding warranty and callback issues of public school construction projects completed utilizing the CM at-Risk method when compared to those completed utilizing the Design-Bid-Build method.
    - Survey responses to the number of warranty/callback issues and cost of warranty/callback issues questions were tested.

CHAPTER 4:

RESEARCH DESIGN AND METHODS

4.1 Quantitative Rationale

This study applied quantitative methods to the collection and analysis of historical data from completed public school projects in Florida, Georgia, North Carolina, and South Carolina. The rationale for the utilization of quantitative methods for this study followed the guidelines provided by Creswell (2009). First, the research was directed at a construction industry issue and was conducted by a researcher with a background in the same field. As has previously been described, the construction industry is situated in the post-positivist philosophy with a long history of utilizing the scientific method for problem solving and management issues. Second, the research employed a two-stage, linear, quantitative data collection and analysis strategy targeting historical records in stage one and survey data in stage two of the research (Singleton & Straits, 2010; Babbie, 2011). And finally, both sets of data were analyzed utilizing statistical procedures and hypothesis testing. All three of these scenarios fell within the guidelines for utilization of quantitative methods of research.

4.2 Project Variables and Performance Metrics

The following measures and indices were formulated and adapted from cost, schedule, quality, and claims project performance information identified in the literature review that map to the operational definition of project delivery method. These performance metrics were then utilized as the dependent variables described in the research analysis section. The metrics are comprised of quantitative data collected utilizing the two-stage historical data collection and survey methods as described in the sections that follow. Tables displaying the cost and time metrics are provided at the end of those sections. A complete list of terms is provided in the Glossary.

4.2.1 Cost Variables

Costs were limited to the design and construction costs associated with the actual building and supporting sitework and did not include the acquisition of land, extensive roadwork outside of the project site, or owner furnished equipment. As previously discussed in the Cost vs. Value section, the factors related to operational or life cycle costs were beyond the scope of the current study and therefore, were also not included. All costs were normalized to 2012 dollars utilizing factors provided by RS Means (2013) which will be explained in the analysis section. The construction and design cost variables collected from the school projects documents under study were:

- Original Contract Cost ($) is the amount listed in the construction contract and entered as Original Contract Sum on the Contractor's Application for Payment.
- Preconstruction Cost ($) is the amount listed in the construction contract payable to the contractor for preconstruction services if applicable.

- Other Cost ($) includes the amounts listed on separate contracts including sitework or other scopes and phases of work that were not included in the Original Contract Sum, but were required in order to complete the entire project scope.

- Final Contract Cost ($) is the amount entered as the Contract Sum to Date or other adjusted total amount listed on the Final Contractor's Application for Payment.

- Original Design Cost ($) is the fee amount listed in the design contract. In cases where a percentage fee was listed, the amount was calculated based on the architect contract terms.

- Final Design Cost ($) is the total fee amount listed on the architect's Final Invoice.

It should be noted that it was observed during the data collection phase that architect reimbursable costs were not being reported by the districts in a uniform manner. Some architects had included reimbursable fees as a line item within their gross billing, while others separated reimbursable fees out as separate costs on separate invoices, and others did not mention them at all. An effort was made to segregate reimbursable costs to enable separate testing in order to determine whether there was a statistically significant difference between the Final Design Cost variables or Final Project Cost metrics when utilizing design fees including and excluding the segregated reimbursable costs. It was later determined through analysis that there was not a statistically significant difference between the Final Design Costs or the Final Project Costs whether or not the segregated reimbursable costs were included. Based on this information, the decision was made to include all known reimbursable costs within the Final Design Cost variable and therefore, within the Final Project Cost metric throughout all analytical procedures and reporting.

4.2.2 Cost Metrics

The construction and design cost variables as defined above were utilized to formulate 8 quantitative cost metrics for each project:

- Original Construction Cost ($) is the measure of cost originally contracted to complete all work required to construct the school facility. It includes the originally contracted construction cost plus any preconstruction cost and/or other separate contract costs for sitework or other scopes of work and was computed as: *Original Construction Cost ($) = Original Contract Cost ($) + Preconstruction Cost ($) + Other Cost ($)*

- Original Project Cost ($) is the measure of cost originally contracted to complete all work required to design and construct the school facility. It includes the Original Construction Cost plus the Original Design Cost and was computed as: *Original Project Cost ($) = Original Construction Cost ($) + Original Design Cost ($)*

- Final Construction Cost ($) is the measure of total cost to complete all work required to construct the school facility. It includes the Original Construction Cost and any costs associated with change orders, fees, or other adjustments and is computed as:

Final Construction Cost ($) = Original Construction Cost ($) + Change Orders, Fees, Adjustments Costs ($)

- Final Project Cost ($) is the measure of total cost to complete all work required to design and construct the school facility. It includes the Final Construction Cost and Final Design Cost and is computed as:

  Final Project Cost ($) = Final Construction Cost ($) + Final Design Cost ($)

- Construction Cost Growth (%) represents the percentage of cost growth (positive or negative) over the duration of the construction period. It reveals variability due to the construction cost of changes and is computed as:

  *Construction Cost Growth (%) = [(Final Construction Cost ($) – Original Contract Cost ($)) / Original Contract Cost ($)] * 100*

- Project Cost Growth (%) represents the percentage of cost growth (positive or negative) over the duration of the project period. It reveals variability due to the design and construction costs of changes and is computed as:

  *Project Cost Growth (%) = [(Final Project Cost ($) – Original Project Cost ($)) / Original Project Cost ($)] * 100*

- Unit Cost ($/SF) represents the square foot cost of construction for a school facility and was determined by dividing the Final Project Cost by the Gross Square Foot (SF) area of the school facility:

  Unit Cost ($/SF) = Final Project Cost/Facility Gross SF

- Student Cost ($/Student) represents the per student cost of construction for a school and was determined by dividing the Final Project Cost by the Student Capacity of the facility:

  Student Cost ($/Student) = Final Project Cost/Facility Student Capacity

Table 4.1 – Cost Metrics

Variable	Metric	Formula
Cost	Original Construction Cost ($)	*Original Contract Cost ($) + Preconstruction Cost ($) + Other Cost ($)*
Cost	Original Project Cost ($)	*Original Construction Cost ($) + Original Design Cost ($)*
Cost	Final Construction Cost ($)	*Original Construction Cost ($) + Change Orders, Fees, Adjustments Costs ($)*
Cost	Final Project Cost ($)	*Final Construction Cost ($) + Final Design Cost ($)*
Cost	Construction Cost Growth (%)	*[(Final Construction Cost ($) – Original Contract Cost ($)) / Original Contract Cost ($)] * 100*
Cost	Project Cost Growth (%)	*[(Final Project Cost ($) – Original Project Cost ($)) / Original Contract Cost ($)] * 100*
Cost	Unit Cost ($/SF)	*Final Project Cost/Facility Gross SF*
Cost	Student Cost ($/Student)	*Final Project Cost/Facility Student Capacity*

4.2.3 Time Variables

The following construction and project time variables were collected from the projects under study and were then utilized to formulate the time metrics described in the next section.

- Design Start is the date listed in the design contract or, in the case that date was not provided, the date the design contract was executed.
- Construction Start is the date listed in the construction contract or as listed in the Notice to Proceed.
- Original Completion is the substantial completion date listed in the construction contract or in the Notice to Proceed. Alternatively, the date can be computed by adding the number of days listed in the construction contract to the Construction Start.
- Revised Completion is the date the Original Completion date is shifted to by adding (subtracting) the number of days allowed (deducted) via change order.
- Substantial Completion is the date listed on the Certificate of Substantial Completion.
- Final Completion is the date the architect executed the Contractor's Final Application for Payment.

4.2.4 Time Metrics

The time variables listed in the previous section were utilized to develop the 8 quantitative metrics of time for each project:

- Planned Construction (Days) is the contracted construction duration in days. It was derived by counting the number of days between the Construction Start date and the Original Completion date. Alternatively, it was sometimes listed in the construction contract.

- Actual Construction (Days) is the actual construction duration in days. It is derived by counting the number of days between the Construction Start date and the Substantial Completion date.
- Planned Project (Days) is the project duration in days. It is derived by counting the number of days between the Design Start date and the Original Completion date.
- Actual Project (Days) is the actual project duration in days. It is derived by counting the number of days between the Design Start and the Substantial Completion date.
- Construction Growth (%) represents the percentage of time growth (positive or negative) over the duration of the construction period. It reveals the time variations (overruns or underruns) required to complete the construction.

  *Construction Growth (%) = [(Actual Construction (Days) – Planned Construction (Days)) / Planned Construction (Days)] * 100*
- Project Growth (%) represents the percentage of time growth (positive or negative) over the duration of the design and construction periods. It reveals the time variations (overruns or underruns) required to complete the project.

  *Project Growth (%) = [(Actual Project (Days) – Planned Project (Days)) / Planned Project (Days)] * 100*
- Project Intensity (SF/Day) was utilized as a measure of productivity showing the square foot area of school facility constructed per schedule day and is derived:

  Project Intensity (SF/Day) = Facility Gross SF/Actual Project (Days)

- Project Intensity ($/Day) was utilized as a measure of productivity showing the volume of work ($) completed per schedule day and is derived:

  Project Intensity ($/Day) = Final Project Cost ($)/Actual Project (Days)

Table 4.2 – Time Metrics

Variable	Metric	Formula
Time	Planned Construction (Days)	*Number of days between the Construction Start date and the Original Completion date*
Time	Actual Construction (Days)	*Number of days between the Construction Start date and the Substantial Completion date*
Time	Planned Project (Days)	*Number of days between the Design Start date and the Original Completion date*
Time	Actual Project (Days)	*Number of days between the Design Start date and the Substantial Completion date*
Time	Construction Growth (%)	*[(Actual Construction (Days) – Planned Construction (Days)) / Planned Construction (Days)] * 100*
Time	Project Growth (%)	*[(Actual Project (Days) – Planned Project (Days)) / Planned Project (Days)] * 100*
Time	Project Intensity (SF/Day)	*Facility Gross SF/Actual Project (Days)*
Time	Project Intensity ($/Day)	*Final Project Cost ($)/Actual Project (Days)*

4.2.5 Quality Metrics

The owner's level of satisfaction with the quality of the project has been measured utilizing the metrics of Product Quality and Service Quality. Ratings of owner satisfaction with regard to the Product (workmanship-overall project, building exterior and interior, and environmental systems) and the manner in which project team members provided Service (responsibilities-controlling costs, schedule, and quality) utilizing communication, collaboration, and cooperation were obtained utilizing survey questions. Survey development and distribution will be discussed in a later section. A copy of the survey is provided in Appendix B.

Additionally, 2 empirical measures of building readiness (a subset of Product Quality) and 1 empirical measure of Overall Quality were developed. First, the Readiness metric was developed from schedule data to establish the amount of time in days that was utilized by the contractor to finish all incomplete (punchlist) and other miscellaneous items of work. Readiness is the measure of days between the date of Substantial Completion and the date of Final Completion.

The second empirical measure of Readiness was developed utilizing owner input obtained during the survey process regarding the recorded numbers and costs of warranty and callback issues. The number of issues and their severity (in terms of cost) was utilized to establish this comparative measure of building readiness and product quality.

The final empirical measure of Overall Quality was obtained through the collection of owner provided construction claims data during the survey process. Since Construction Claims are often the product of many factors including inadequate communication, unclear project documents, poor relationships, low productivity, insufficient service, and inferior workmanship and often lead to increased costs and schedule overruns (Saporita, 2006; Akintoye & MacLeod, 1997; Gordon, 1994; Kangari, 1995), Construction Claims can be utilized as a representative measure of Overall Quality performance. The number of claims and their severity (in terms of cost) were utilized in an attempt to establish this comparative measure of Overall Quality.

4.3 Sample Design

4.3.1 Unit of Analysis

In order to reduce the amount of variability between the projects selected for the research, only new construction of full facility public school projects were utilized as the units of analysis. Higher education facilities, renovations and additions to existing schools, and ancillary buildings such as administration and office structures were excluded from this study. This unit of analysis determined the selection of projects with similar typologies enabling a relatively uniform comparison of facilities with similar size, cost, design, and construction characteristics. This was an improvement on the Konchar and Sanvido (1998) research, which as previously noted, was criticized by Williams (2003) for their utilization of widely varied project sizes and types. It also ensured a large population of projects since funding for education and new school projects are among the largest items within state and local budgets (US Census, 2011; Oliff, Mai, & Palacios, 2012; McNichol, Oliff, & Johnson, N, 2011).

As a matter of convenience, the projects selected for this research were located in the states of Florida, Georgia, North Carolina, and South Carolina. And, although states often differ in the manner in which funds for capital projects are raised and administered, the states selected were similar in that the majority of funding for their public school projects is provided from county or district levels (Filardo, Cheng, & Allen, 2010). And finally, in order to reduce project variability related to construction materials, methods, and designs, the study population included only those projects completed after 2005.

4.3.2 Population and Sampling Frame

As noted above, the population included all new public school projects constructed in Florida, Georgia, North Carolina, and South Carolina that opened in 2006 or later. Based on the information obtained from the Departments of Education in each state, a list was compiled of all districts completing new school projects from January of 2006 to 2012 (FLDOE, 2012; GADOE, 2012; NCDOE, 2012; SCDOE, 2012). This information was combined and tabulated in order to develop the sampling frame identifying 829 new public school projects constructed across 247 of the more than 460 school districts in the 4 state study area as shown in Figure 4.1.

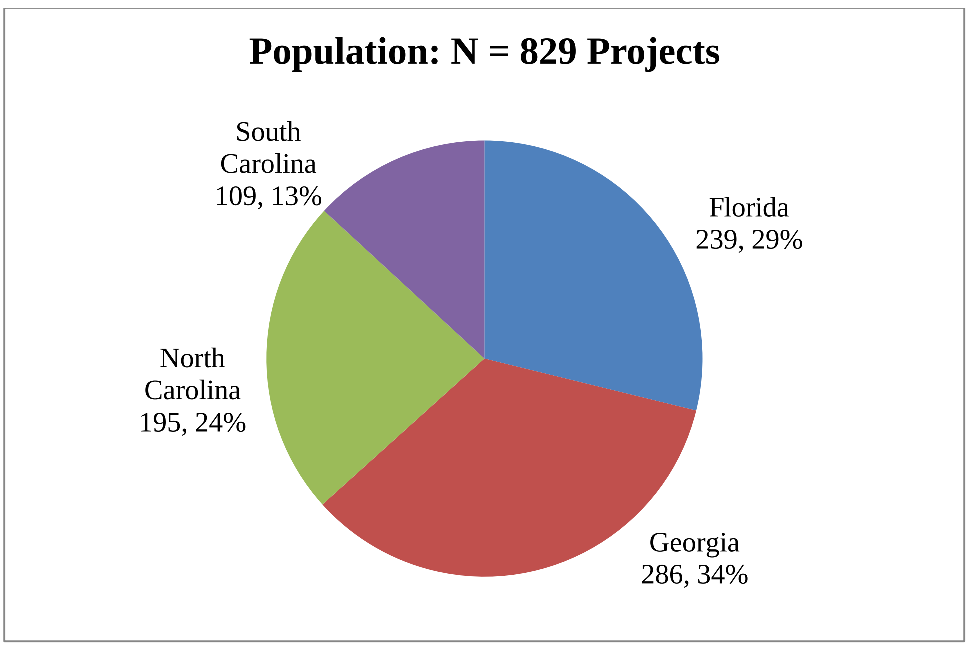


Figure 4.1 Research Population

Based on this population *N*, the following formulations were utilized to determine the necessary sample *n* required for the analysis. First, it was necessary to select the sample size *n* from the population *N* required to estimate the mean μ performance measures of the data to be analyzed. Therefore, the following equation was selected for this purpose (Scheaffer, Mendenhall, Ott, & Gerow, 2012):

$$n = \frac{N\sigma^2}{(N-1)\,D + \sigma^2}$$

where n = the estimated sample,

N = the population (829),

σ = \$5,000,000 (conservative estimate, no prior information available)

where \$20,000,000 is the estimated mean cost with

R = the range of \$20,0000, with \$10,000,000 being the lower confidence limit and \$30,000,00 being the upper confidence limit and

$$\sigma \approx \frac{1}{4} R$$

$$D = \frac{B^2}{4}$$

where the bound on the error of estimation of magnitude

B = \$1,000,000 (conservative estimate, no prior information available)

So, for the purpose of this research,

$$n = \frac{(829)\,(5{,}000{,}000)^2}{(829-1)(\frac{1{,}000{,}000^2}{4}) + (5{,}000{,}000)(5{,}000{,}000)}$$

n = 89.33

Therefore, the minimum number of project datasets required to meet the needs for the research analysis was calculated to be 90.

Next, since survey data were to be analyzed, it was necessary to estimate the sample size *n* required to obtain proportional response data. The following equation was utilized for this purpose (Scheaffer, Mendenhall, Ott, & Gerow, 2012):

$$n = \frac{Npq}{(N-1)D + pq}$$

where *n* = the estimated sample,

N = the population (829),

$q = 1 - p$, and p = .05 (conservatively estimated since no prior information was available), and

$$D = \frac{B^2}{4}$$

where the bound on the error of estimation of magnitude B = 0.1 (conservatively estimated since no prior information was available)

So, for the purpose of this research,

$$n = \frac{(829)(0.5)(0.5)}{(829-1)\ \frac{0.1^2}{4} + (0.5)(0.5)}$$

n = 89.33

Therefore, the minimum number of survey responses required to meet the needs for the research analysis was calculated to be 90. Note that the formulas utilized for the mean and proportional requirement calculations were essentially the same and, based on the estimated mean construction cost, range, and boundaries selected, the calculations resulted in the same minimal requirements for both the historical and survey data.

Based on the calculations above and a desire to exceed the minimum requirements, the minimum target was set at 100 project datasets and survey responses with a goal of obtaining 120. Table 4.3 was then developed to compute the percentages of completed projects (distributions) from each state. These percentages were utilized to establish the minimum target and goal quantities required from each state in order to obtain a sample maintaining properties similar to the population as shown in columns 4 and 5 of the table. As will be described in later sections and shown in Figure 4.2, minimum target levels for all states were met based on the need calculations at the 100 project overall minimum target; however, state goals were only met in South Carolina and North Carolina to meet the overall goal of 120 projects.

Table 4.3 – Planned Distribution by State

State	**Completed School Projects**	**% of Total Projects**	**Minimum Target, 100 Projects**	**Goal, 120 Projects**
Florida	239	29%	29	35
Georgia	286	34%	34	41
North Carolina	195	24%	24	28
South Carolina	109	13%	13	16
Total Projects	829	100%	100	120

4.4 Stage One Data Collection

4.4.1 Historical Data

As described in the research rationale section, this study involved a two-stage data collection and analysis procedure. The historical data collection in stage one was directed at all known projects within the population. However, a concerted effort was focused in areas of larger populations in order to increase the opportunity for obtaining large volumes of data from districts that have been actively expanding their school systems while utilizing both Design-Bid-Build and CM at-Risk delivery methods.

In order to ensure the quality of the data being collected, the actual project files and records were utilized to establish, confirm, and validate project cost and schedule data. Note that this is the first and only known study conducted utilizing actual project documents for data collection purposes and is an improvement over the Konchar (1997) research, in which a survey data collection mode was utilized. In that study, although calls were made to collect missing information or to verify information provided by those other than owners (Moore, 1998), actual project documents were not collected or reviewed by the researchers in order to verify the key project cost and time performance information utilized for their ensuing analysis.

The primary reason this data collection procedure was employed is due to an early attempt to gather preliminary project data in Georgia. During that exercise, a data collection form was distributed to district administrators with a request to provide contract cost and schedule information. Examination of the responses obtained during that period revealed that, contrary to the verbal directions provided during phone conversations and the written instructions provided in both email distribution and within the body of the form, some respondents were apparently utilizing their recall ability or other sources to complete the forms. For example, answers provided included rounded responses such as, $18 million or July of 2008, rather than the expected responses of the actual figures of $18,751,862 and July 24, 2008. Therefore, the final determination was that only those projects for which copies of actual project records were obtained would be included within the research. Data collection forms would be utilized to help facilitate the collection of the project, district, and project team demographic information.

The documents targeted for collection during this stage of the research were the: Construction Contract Agreement, Architect Contract Agreement, Notice to Proceed, Certificate of Substantial Completion, Final Construction Application for Payment, and Final Architect Invoice/Billing. Additionally, a copy of the Final Change Order for each project was collected at a later time as is discussed in the Data Collection Mode section that follows. These documents were targeted due to their relatively universal acceptance and widespread utilization across the construction industry and their ability to provide the complete and factual data required for the research. Cost and schedule data were collected enabling computation of the previously described cost and time metrics. Data collected for this work included original and final contract cost and schedule information for both the architect and contractor. Where data were not present in the contract documents, such as student capacity or gross square footage, district or state records were utilized. A complete list of the documents and cost and time variables targeted for collection are listed in Table 4.4.

Table 4.4 – Historical Documents and Data

Document	Data
Construction Contract(s)	Original Contract Cost, Preconstruction Cost, Other Cost, Construction Start Date, Original Completion Date
Architect Contract	Design Start Date, Original Design Cost
Notice to Proceed	Construction Start Date, Original Completion Date
Certificate of Substantial Completion	Substantial Completion Date
Final Application for Payment	Final Construction Cost, Final Completion Date
Final Change Order(s)	Final Construction Cost, Revised Completion Date
Final Architect Billing/Invoice	Design Final Cost

The remaining data to be obtained from the districts focused on school and project team demographics including: owner, architect, and contractor contact information, district and school name, school type (High, Middle, Elementary, other), school size (gross square foot area), school capacity (number of students), and delivery method.

4.4.2 Location of Historical Data

A limited number of states collect and report detailed construction data from their school projects (Vincent & McKoy, 2008). Initial investigations revealed that a wide disparity of historical project records and data were collected and maintained at the state level within the study area. The primary reason behind this may be due in large measure to the fact that the majority of funding responsibility for educational capital projects resides at the local (county or district) level (Filardo, Cheng, & Allen, 2010).

All states within the study area require their districts to submit various forms of information regarding new school projects at different stages throughout the construction life cycle. For example, districts in Florida that construct new schools are required to submit a *Report of Cost of Construction* (Appendix C) data collection form to the Florida Department of Education once the project has been completed. The reports submitted in Florida include demographic data about the school projects and their locations with more detailed information concerning the number of student or teacher stations to be constructed, gross and net square foot area of the facilities, and costs based on different parameters such as legal and administrative costs, site improvements, and furniture and equipment. The Florida Cost of Construction form does not include information pertaining the project schedule or duration.

However, although all states within the study area collect data regarding the construction of their public schools, the data are not collected in a uniform manner nor is it maintained by all states for an extended period of time. For example, at the time of the initial investigation, the database maintained at the state level in South Carolina included only the date original construction documents were submitted for review, the name of the county or school district submitting those documents, and the name of the school to be constructed. In contrast, Florida, North Carolina, and Georgia maintain databases containing a wide variety of project information. For example, the Florida DOE utilizes the information collected from the districts to calculate construction and plant facility costs per square foot and costs per student ratios and to track budgets resources utilized for school construction funding and other issues. The information is shared among developing districts through the FL DOE online database (Appendix D).

One problem with the Florida system noted in discussions with the DOE staff is that the database does not always contain up-to-date information. The staffer explained the reasons for this were twofold. First, due to time constraints, budget issues, or other extenuating circumstances, districts did not always provide information in a timely manner. Second, database maintenance is not always completed timely at the state level. These explanations reveal issues inherent to data collection and database management as a whole and the issues appear to be common across all states within the sample area.

Hard copies of actual project documents were not available at the state level in any state with the exception of Georgia. During an investigation of the Georgia statutes regulating school funding, a review of Section 160-5-4-.16 (a) 8s of the Official Code of Georgia, Guideline for Receiving State Capital Outlay Funds and associated documents revealed that districts in Georgia constructing new schools are required to submit a large number of the previously listed documents necessary for the current research in order to obtain state funding for their projects. Among the documents required to be submitted to the state are the: Construction Contract Agreement, Architect Contract Agreement, Construction Applications for Payment, and Final Architect Certification of Construction and Architect Costs. These documents are held at the Georgia DOE Facilities Services office in Atlanta. The remaining documentation required for the research is not collected by the state. A request to review and copy the Georgia DOE documents was submitted; however a resolution to this issue could not be immediately resolved as will be described in the following chapter.

Thus, the preliminary investigation revealed that the project documents and data required to conduct the planned research were generally not available at the state level for any of the states within the study area. Therefore, plans were developed in order to collect the historical records from the multiple sources and locations across several states.

4.4.3 Historical Data Collection Mode

Utilizing the previously developed sampling frame, school districts in Florida, Georgia, North Carolina, and South Carolina were contacted by phone and email in order to locate the person within the district responsible for construction of school facilities. For the purpose of this study this person is known as the district manager. Once the initial contact was made in each school district, the introductory letter describing the research (Appendix E) was sent to the district manager along with a project data collection sheet (Appendix F) including instructions for completion and a request for copies of the project documents previously listed in Table 4.4.

4.5 Stage Two Data Collection

4.5.1 Survey Data

Once the historical data collection work was completed for a particular project, a survey questionnaire was distributed to the district manager. The survey was utilized to obtain reliable district manager perceptions of the product quality of the new facility and the quality of service provided by the construction and design teams during the design and construction process. The focus on recently completed projects was expected to improve the quality of the data being provided. The data obtained served as the performance measures for the previously described Service Quality and Product Quality metrics. The objective was to obtain one completed survey to represent each project for which the historical data collection had been completed in stage one.

4.5.2 Survey Instrument

A copy of the survey instrument developed for this research is included in Appendix B. The original questionnaire utilized for the Konchar (1997) study (Appendix G) was utilized as the basis of design for the current research survey instrument. Note however, that the objective of the current research was not to replicate the Konchar (1997) study. Nonetheless, because of the widespread acceptance of the Konchar and Sanvido (1998) research, which was completed utilizing the Konchar (1997) data, it was beneficial to utilize the original survey as a starting point for the current study. The structure and content of the Konchar questionnaire was scrutinized by the researcher to ensure that questions were consistent and effective at providing reliable and valid responses. Additionally, questions were compared to the guidelines provided by Dillman (2009) in order to correct for improperly structured or worded questions. Visual design properties were also reviewed, updated, and enhanced to provide a contemporary and professional appearance to the document.

Within this process, questions were added, deleted, or modified as required to obtain the information necessary to satisfy the needs of the current research. For example, all questions were designed to narrow the focus to public school projects in lieu of the variety of project types as was the case in the Konchar questionnaire. Additionally, the Konchar format had been developed in sections to collect facility and delivery system data in the initial sections, performance data in the mid-sections, and reasons for respondent answers in the closing sections (Konchar, 1997). This linear collection approach allowed for collection of the objective data at the beginning of the survey followed by the more subjective data in the closing sections (Ibid). For the purpose of the current study, school and district information were included in the initial section, but all remaining demographic questions were provided in the closing section. Construction and project cost and schedule performance questions were not included within the survey since those data had previously been collected in stage one. Questions regarding the cost issues associated with claims and warranty issues were positioned at the end of the survey, just prior to the demographics. This left the main body of the survey dedicated to the quality performance of the construction, design, and project teams in the production of the finished product.

Other modifications were required to introduce elements of modern terminology. For example, in Section VI: Project Team Selection portion of the Konchar (1997) survey, the first question read:

> Mark the appropriate oval for each of the following attributes of your project team:
>
> Project Team Selection
>
> ( ) Open Bidding ( ) Prequalified Bidding
>
> ( ) Negotiated Contract ( ) Contract Documents

Although the selection options were appropriate at the time, these selections did not provide for the possible responses of: Qualifications-Based Selection, Best-Value Selection, or other variations utilized for the procurement of construction services in today's market. Research shows that state agencies are currently adopting these methods of procurement (Abdelrahman, Zayed, & Elyamany, 2008). Thus, it was important for the survey questions to be modified utilizing appropriate modern terminology in order to obtain proper responses and useful information in the current period.

Overall, the survey instrument was designed to facilitate the efficient collection of reliable data required for analysis of the previously identified performance metrics of time, cost, and quality for the projects under study.

4.5.3 Survey Mode

The survey was hosted on an internet based platform and invitations to complete surveys were distributed via email containing a link to the web-based survey. Respondents were then able to access their individually coded surveys, completing them in one sitting or returning to them at the most opportune time to meet their schedules. Consideration was given to those respondents that may have preferred a more traditional hard copy method or had difficulty accessing an online platform and, although these issues did not occur, alternative distribution through postal mail or email attachment was developed. Care was taken to ensure that the survey questions presented in each mode had the same meaning to all respondents and that the questions would elicit the appropriate types of responses from those responding to the survey. A modified Dillman (2009) approach for implementing the surveys was applied as follows:

- Personalized all contacts with respondents
- Performed multiple methods of contact, each with a different look and appeal
    - Information about the survey was provided in phone calls, introductory letter, and instructions during the initial contacts for the stage one data collection
    - A brief phone discussion of the research was conducted with each respondent prior to distribution of the questionnaire
    - The questionnaire was distributed including a detailed cover letter
    - Thank you and reminder emails were distributed as applicable
    - A personal phone contact was made to those not responding timely
    - A replacement questionnaire was distributed as required
    - Final appeals were made to non-respondents by phone and email as required

Due to the importance of reaching the minimal number of targeted responses noted in Table 4.3 and the relatively small number of surveys distributed, every effort was made to control for nonresponse and increase the response rate. Per the Dillman approach listed above, personal contacts and follow-ups were made with the respondents in order to support the effort, reduce survey errors, and increase survey response rates (Ibid). Prior to the distribution of the survey, a personal contact was made to the district manager that would be participating in the survey process. The overall research and confidentiality agreement were explained and the manager was asked to gather any required project data necessary to complete the survey. A schedule for the distribution and completion of the survey was then arranged. Providing advanced notice allowed respondents an opportunity to prepare for the survey and helped the researcher to build credibility and trust with the respondents, which served to increase the survey response rate and accuracy (Ibid).

4.6 Pilot Study

A pilot test of the survey instrument utilized in stage two was conducted from April 8 to April 19, 2013. During this period, the survey was distributed to construction managers in 20 of the largest public school districts in the state of Tennessee. These districts were selected as a convenience sample outside of the actual study area and the data collected will not be utilized in the actual study in order to eliminate the possibility of bias or data corruption. Utilization of public school district managers for the pilot study provided useful feedback from the perspective of respondents that are very similar to those that will be participating in the actual study. Prior to distribution of the survey, a phone discussion was completed with each district manager or his representative explaining the basis of the research and the pilot test. Respondents were asked to complete the survey and to note any problematic questions and any structural or formatting issues within the survey questions or the survey instructions.

Following the distribution and return of the survey, respondents were contacted to discuss their perception of the overall survey in order to determine problematic issues that would need to be addressed. Overall, 11 completed surveys were returned from the

20 district construction managers for a response ratio of 55%. The following written comments were obtained:

- "I do not have any real suggestions to offer in modifying your survey. I felt it is concise in its questioning and appeared tailored to the data that you are trying to retrieve."
- "It made sense to me. The only item that I would possibly look at would be the format for the contract values. I would set it up where it automatically changed to currency. With these large projects I could see where someone could leave off a zero."
- "The survey bogged down on design cost and dates page with information that is archived, exact dates and figures are not readily available. I quit the survey at that point because it would take several hours to assimilate that exact data. Prior to that I would rate it as well above average in design. Had the cost and scheduling data been estimates rather than specifics then I would have been comfortable continuing."
- "I thought the survey was straight forward and easy to understand."

The cost and schedule data entry issues noted above were rectified. While conducting the actual research, it was not necessary to include survey questions related to these issues since the cost and schedule data were received during the historical data collection stage.

4.7 Institutional Review Board Approval

Approval was provided for both stages of the research by the Clemson University Institutional Review Board (IRB) and copies of the approval letters are provided in Appendix H.

CHAPTER 5:

RESEARCH ANALYSIS AND FINDINGS

5.1 Introduction

This Chapter begins with an explanation of the assimilation, validation, and verification of the historical and survey data followed by a description of the data distribution. The procedures utilized to conduct the testing and analysis are described along with a detailed explanation of the results obtained for each individual performance metric. A summary of the findings and a detailed discussion regarding their implications will be presented along with recommendations in the following chapter.

5.2 Data Assimilation

5.2.1 Historical Data

The data collection process began in May of 2012 and was completed in December of 2013. Initial phone and email contacts were made to district managers and data collection forms were distributed utilizing the procedures described in Chapter 4. Follow up calls and emails were utilized to communicate with district managers or their representatives throughout the process. Copies of project documents were collected via postal mail, email, and a number of onsite meetings during which the researcher was able to review and copy the pertinent project documents directly from district files.

Various levels of cooperation were obtained from the district managers. Many of those contacted responded favorably to the research, freely providing documentation and other information about their programs during both phone and email discussions. Others were a little resistant and required numerous follow up contacts in order to eventually complete the project file containing all required documents. Although no scientific data collection method was employed to collect reasons for the resistance, those most often cited were due (in no particular order) to:

- labor and copy costs of participation
- limited access to documentation
- too busy due to staff reductions or existing projects

The remaining district managers either would not return emails or calls, or began the process and then were either unwilling or not able to provide the complete set of project documents due to unknown reasons. Partial data collection was achieved on more than 200 qualifying projects with approximately 170 of those project files nearing completion.

Districts in North Carolina, Florida, and South Carolina were contacted utilizing the procedure described above and the process in Georgia began in the same manner. However, midway through the data collection stage the documents on file at the Georgia DOE became available. A review of all available files was conducted, resulting in the retrieval of partial documents from more than 60 qualified projects. Follow up contacts made to district managers constructing those schools resulted in the completion of 32 additional project files for a total of 44 Georgia projects. The numbers of projects for which complete documents were obtained in the remaining states were: 36 in Florida, 44 in North Carolina, and 25 in South Carolina, for a total of 149 projects.

A follow up data collection effort was completed in order to obtain previously unrequested documents. Late in the data collection process, it became apparent to the researcher that a comparison of project duration modifications associated with change orders should be included within the research analysis. In order to accomplish this task, a review of the final change order for each project would need to be conducted in order to determine whether or not the original completion date had been revised, and if so, by how many days. A review of all previously collected project files was performed. Where files were identified that did not contain final change orders, district managers were contacted, and requests for the documents were made. In cases where final change orders had not been issued or were otherwise not available, written confirmations regarding any project duration changes were obtained from the district managers.

5.2.2 Survey Data

Following the collection of historical data for each project, district managers were sent emails containing links to the research surveys as described in the previous chapter. The district managers were requested to complete the surveys based on their knowledge and perceptions of the recently completed public school facilities for which they had submitted project data. Follow up requests were made by various methods in order to increase survey response with the knowledge that projects that did not receive a completed survey would be eliminated from the study. Overall, there were only 10 projects of the 149 that were eliminated from the study due to non-completion of the survey: 6 projects in Florida, 3 projects in Georgia, and 1 from the state of South

Carolina. This corresponds to a response ratio of 93.3% leaving the total number of projects within the study at 139. Note that two projects were eliminated during the final validation process and testing for outliers as shall be explained in the next section.

5.3 Data Verification and Validation

5.3.1 Historical Data

As noted in the historical data collection section, only original project documents and official records were utilized to provide the cost and time performance data required for the testing and analysis completed within this research. This requirement was initiated to ensure that accurate data were being furnished and to provide a means to verify information entered into the database or in other cases where inconsistencies were detected. Utilization of this method of data collection also provided an opportunity to obtain the most precise and robust results.

The historical documents collected during stage one were separated into individual project files and grouped by state in preparation for the initial screening and validation procedure. Documents were reviewed for accuracy and completeness based on their ability to provide the data required to populate the individual cost, time, and demographic variables necessary to conduct testing and analysis. Where required, data were compared to state provided database information for validation. Historical project data were recorded in an electronic spreadsheet file and sorted in preparation for statistical analysis. Throughout the data collection period extreme care was taken to avoid data recording and entry errors. Cross-checking of project documents with owner, architect, and contractor payment and schedule records was utilized as required to ensure accuracy. Projects for which data were found to be incomplete or unverifiable were eliminated.

As an additional step toward verification and validation, a complete review of all files in comparison to the data collection spreadsheet was completed. At that time, several inaccuracies were detected and corrected. Additionally, 1 North Carolina project was eliminated from the study due to the discovery that the project was only an addition to an existing facility, not a new project. During the analysis stage, a review of possible outliers revealed that 1 of the Georgia projects was not a new, full facility project. This project was removed from the data file dropping the total number of validated projects to 137 as shown in Figure 5.1. Note that the numbers and percentages of projects from each state closely match that of the population previously shown in Figure 4.1.

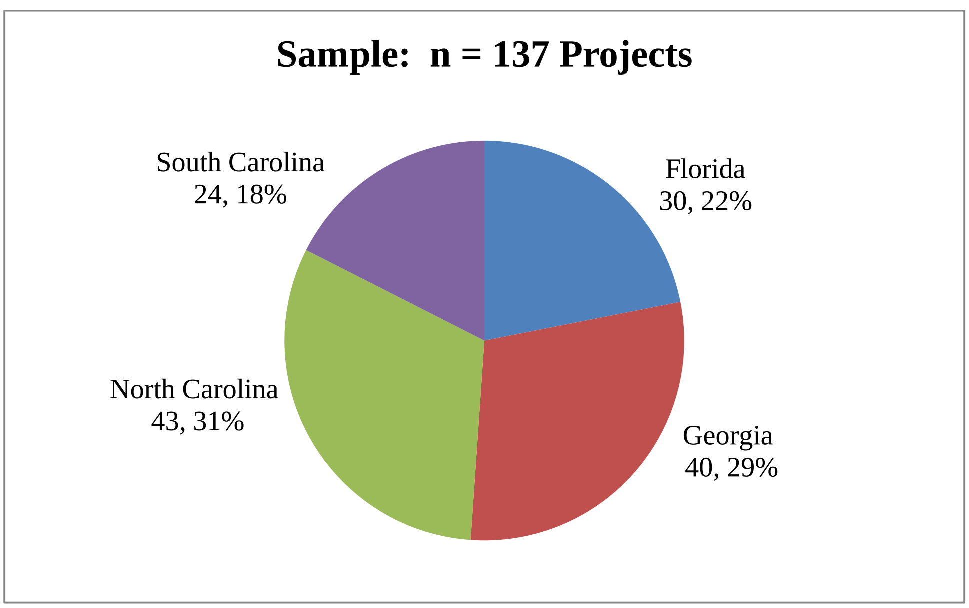


Figure 5.1 Validated Sample

5.3.2 Survey Data

For the stage two data collection, several different efforts were made in order to improve the validity and accuracy of the data. For example, it is expected that providing advanced notice to respondents that the survey was forthcoming and allowing them to utilize existing project records to assist with their responses improved both the validity and precision of the information obtained. Additionally, the personal contact maintained with district managers throughout the data collection process helped to maintain and verify the validity of responses. Furthermore, focusing the research on recently completed projects was expected to assist district manager recall of contractor and architect performance on those projects thus, improving data accuracy. And finally, steps were taken to limit bias. For example, programming of the survey distribution and collection software prior to the survey being distributed prevented respondents from submitting more than one survey or the dispersal of surveys to other parties that could possibly have provided inaccurate information skewing the results.

Once the surveys were completed, the data collected in nominal form were analyzed, formatted, and coded into a numerical format within the survey software program in preparation for statistical analysis. The information was then exported directly into a spreadsheet where it could be merged with the previously entered cost and time data. This direct processing of information reduced the opportunity for data entry errors during transcription. A final check of the complete data file was accomplished by sorting the data by comparative demographic codes to ensure that all data lines in both datasets had transferred accurately.

Note that all data files have been stored in password protected file locations and respondent identifiers were not stored or aggregated with the datasets in order to ensure confidentiality of the data. Merged datasets that included respondent identifiers were utilized during brief periods and no sharing of the merged data files was allowed. All individual confidentiality forms are maintained in a separate location from the datasets and coded study instruments.

5.4 Data Distribution

The distribution of the project data obtained from the 137 sample projects is presented in the following sections. For testing purposes, project data were distributed based on delivery method, project type, state, and all various combinations of these variables. Therefore, a thorough explanation of the distributions is expected to improve comprehension of the research results presented in later sections of this chapter. As will be shown in the following subsections and surmised at the end of the distribution section, distribution of the sample into multiple levels reduces the numbers and ratios of different projects to be analyzed within each category such that the power of the tests to detect statistically significant differences between the project performance measures is diminished.

5.4.1 Project Delivery Method

Figure 5.2 reveals that 86, 63% of the 137 projects included in the overall sample were completed utilizing the Design-Bid-Build method, while 51, 37% of the projects were constructed utilizing CM at-Risk. These distributions support the FMI/CMAA (2007, 2010) evidence of project delivery utilization presented in Figure 2.7. The large numbers of projects and proportional distributions within each category improved the opportunity for obtaining robust results through statistical analysis.

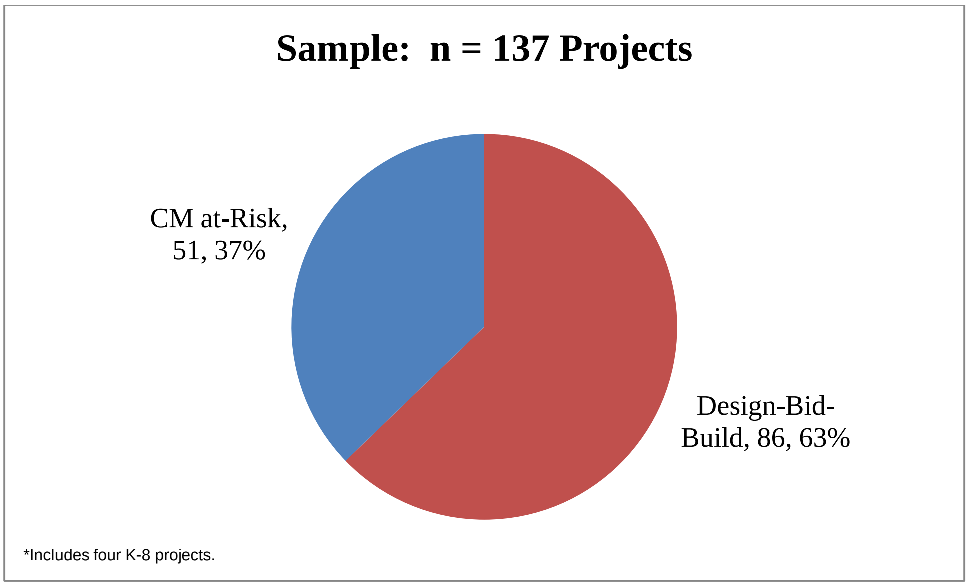


Figure 5.2 Sample Distribution by Project Delivery Method

5.4.2 Project Type

Three types of public school projects were included in the sample: Elementary, Middle, and High schools. As shown in Figure 5.3, the largest proportion of projects included within the sample were of the Elementary project type with 81, 59%, followed by Middle schools at 32, 23%*, and High schools with 24, 18%. The large numbers of projects included within each type, particularly within that of the Elementary type, provide opportunities to obtain robust results from the research analysis.

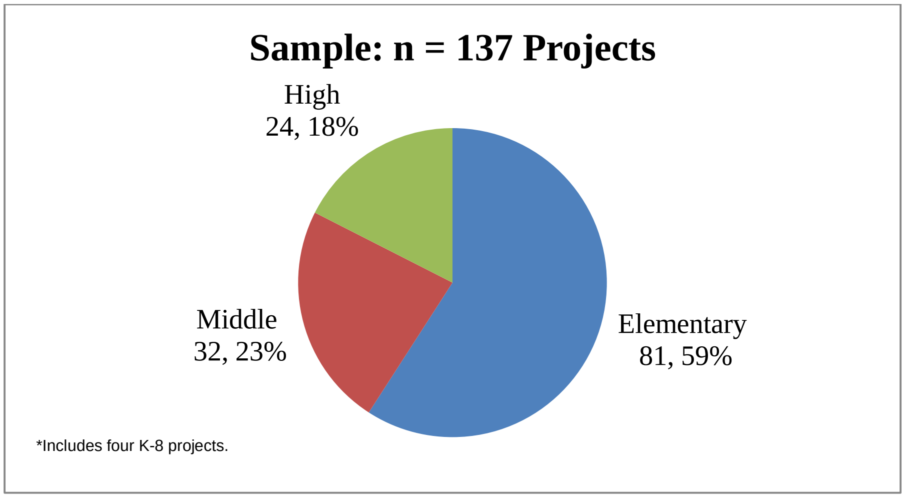


Figure 5.3 Sample Distribution by Project Type

*It must be noted that the data from four K-8 type projects constructed utilizing the CM at-Risk project delivery method were received from districts in Florida during the data collection stage. Noting that these projects did not fit within the defined Elementary, Middle, and High project types, a detailed review of the mean and median values of the project variables: Project Size, Project Cost, Unit Cost, Student Capacity, Construction Duration, and Project Duration from schools constructed utilizing the CM at-Risk method was conducted in order to determine if it was viable for the K-8 schools to be utilized within one of the existing project types.

The K-8 school projects were found to most closely fit the Middle school type. With respect to Project Size, the K-8 mean was less than 1% larger with a difference of only 502 square feet. Similarly, Construction Cost was a relatively good fit with Middle schools, where the mean difference was $845,178, 2.73% larger for the K-8 schools. However, the mean Student Capacity of K-8 projects was significantly larger than that of Middle schools, with a mean difference of 297 students, 25.3% more. The K-8 Student Capacity more closely resembled that of High schools, where the difference in means was only 19 students, 1.3% less. The differences noted above were most pronounced within the analysis of the Unit Cost and Student Cost variables. The mean Unit Cost for the K-8 schools at $199.52 was shown to be $14.39 per square foot, 7.8% more than Middle schools although, the median Unit Cost of the Middle type at $198.02 was a relatively good fit. The K-8 mean Unit Cost more closely resembled that of the High school type, where the difference in means was only $5.42 per square foot, 2.8% less. The K-8 per Student Cost of $23,141 was shown to be $5,072, 18%, less than that of Middle schools. The K-8 Student Cost aligned better with the Elementary type, having a difference of only $2,703, 10.5% less. The mean Actual Construction duration for the K-8 schools was most like that of the Middle school type, with a mean difference of 75 days less for K-8 schools. However, the mean Actual Project duration was more like that of the Elementary type, with a mean difference of 42 days less. Similarly, the K-8 mean Project Schedule Growth percent was most like that of the Elementary type, with a mean difference of 0.5% less.

Based on the overall analysis of the K-8 schools, the final determination was to include the 4 projects within the Middle school type. However, a separate level of testing excluding the K-8 data was conducted as a comparative measure to ensure that inclusion of the differences specific to K-8 schools was not able to influence the significance of the overall results. Differences experienced are noted within the section describing each variable tested.

5.4.3 Project Delivery Method and Project Type

Figure 5.4 presents the distribution of projects by both project delivery method and project type. Note that all project types maintained a similar distribution to that of the overall sample distributed by project delivery method alone. Elementary projects

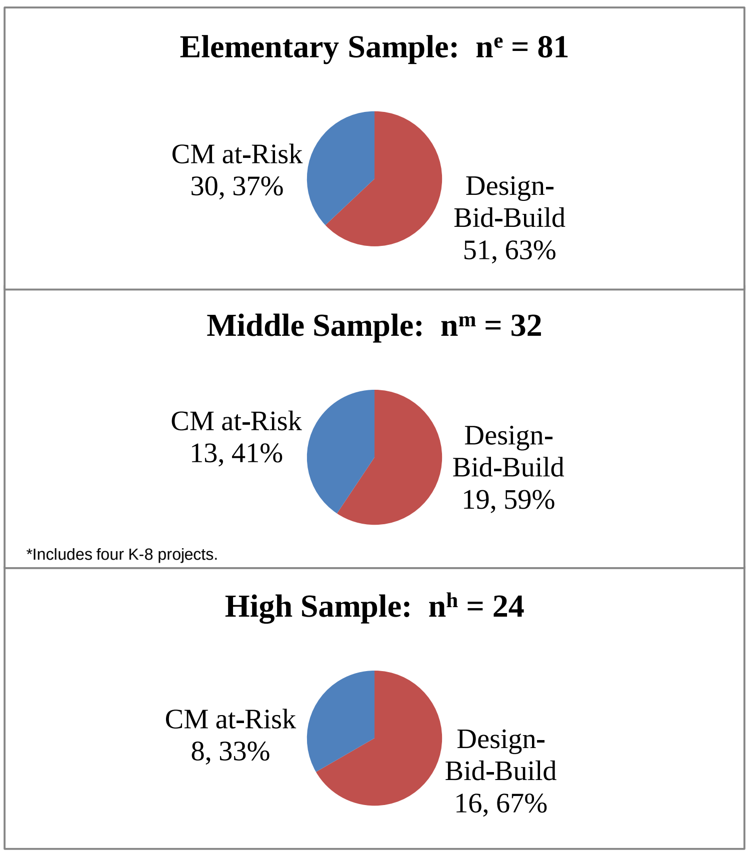


Figure 5.4 Sample Distribution by Project Delivery Method and Project Type

were distributed at 37% CM at-Risk and 63% Design-Bid-Build, Middle schools at 41% CM at-Risk and 59% Design-Bid-Build, and High schools with 33% CM at-Risk and 67% Design-Bid-Build. Examination of this distribution provided confirmation that sample data were relatively uniform across all project types providing the opportunity for robust results from analysis at both the overall and project type levels.

5.4.4 State

The sample distributed by state was previously presented as Figure 5.1 during the verification and validation process discussion and is shown below in Figure 5.5 for purposes of clarity. It is evident from the figure that the sample contains relatively large numbers of projects from each state and that the distribution fairly represents the planned proportional distributions targeted at 29% from Florida, 34% from Georgia, 24% from North Carolina, and 13% from South Carolina as originally presented in Table 4.3.

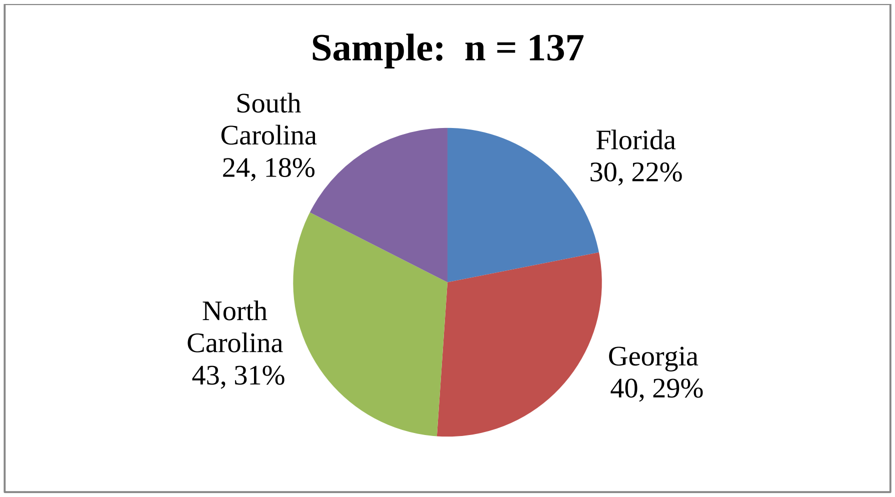


Figure 5.5 Sample Distribution by State

5.4.5 Project Delivery Method and State

Distributions by project delivery and state are provided in Figure 5.6 that follows. Note that North Carolina, with 16 CM at-Risk and 27 Design-Bid-Build projects had the same proportional distribution, 37% and 63% respectively, as that of the overall sample previously presented in Figure 5.2. The South Carolina projects had a similar distribution to the sample, although not quite as exacting, with 21% CM at-Risk and 79% Design-Bid-Build. The relatively large number of projects constructed with each method within North Carolina and South Carolina allowed for robust comparison of the performance metrics at this level. Additionally, the similarities of the distributions between the project

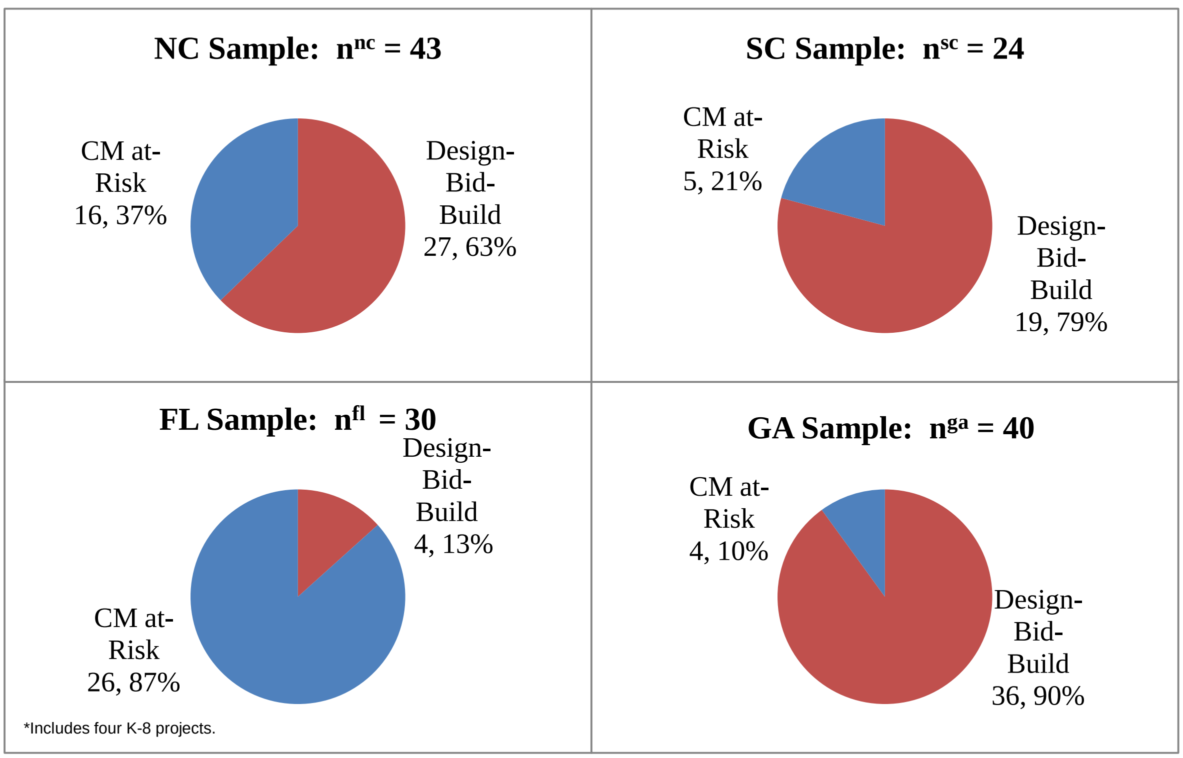


Figure 5.6 Sample Distribution by Project Delivery Method and State

data of these states and the overall sample allowed for an important means to corroborate the results obtained at the overall level. Conversely, projects across Florida were constructed primarily utilizing CM at-Risk; whereas in Georgia, Design-Bid-Build was the predominant method utilized. Results obtained through analysis of Florida or Georgia project data in isolation were examined with increased scrutiny due to the reduced percentage of projects included within each project delivery method category.

5.4.6 Project Type and State

Distributions by project type and state as presented below revealed that the largest proportions of all schools in each state remained Elementary schools as previously shown

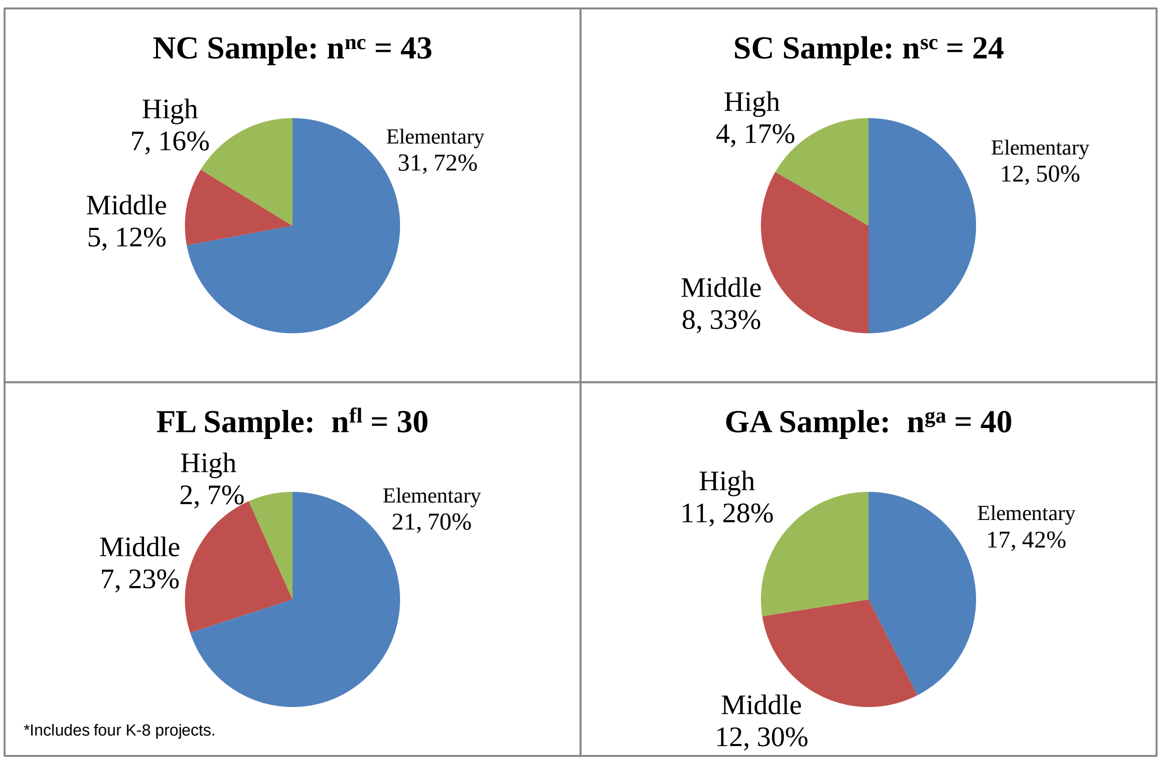


Figure 5.7 Sample by Project Type by State

for the overall sample in Figure 5.2. Slightly smaller proportions of both Middle and High school projects, 12% and 16% respectively, were obtained from North Carolina, increasing the proportion of Elementary schools in that state to 72%, the highest within the sample. Alternately, slightly larger proportions of both Middle and High schools, 30% and 28% respectively, were collected from Georgia. The South Carolina distribution contained a slightly larger proportion of Middle schools with 33% and maintained a relatively even proportion of High school projects at 17%. A smaller proportion of High school projects, only 7%, were submitted from the state of Florida. The importance of the differences noted will become immediately obvious when these projects are further distributed by delivery method in the next section.

5.4.7 Project Delivery Method, Project Type, and State

A distribution of the sample data utilizing the categories of project delivery method, project type, and state distributed the data such that many project categories were beyond the level of viable comparative analysis. For example, as shown in Figure 5.8, there were no Design-Bid-Build Middle or High school projects in the state of Florida and no CM at-Risk Elementary schools in Georgia. Similarly, only 2 CM at-Risk Middle and High schools existed at this level in Georgia, while only 1 High, 2 Middle, and 2 Elementary schools were constructed utilizing CM at-Risk in South Carolina.

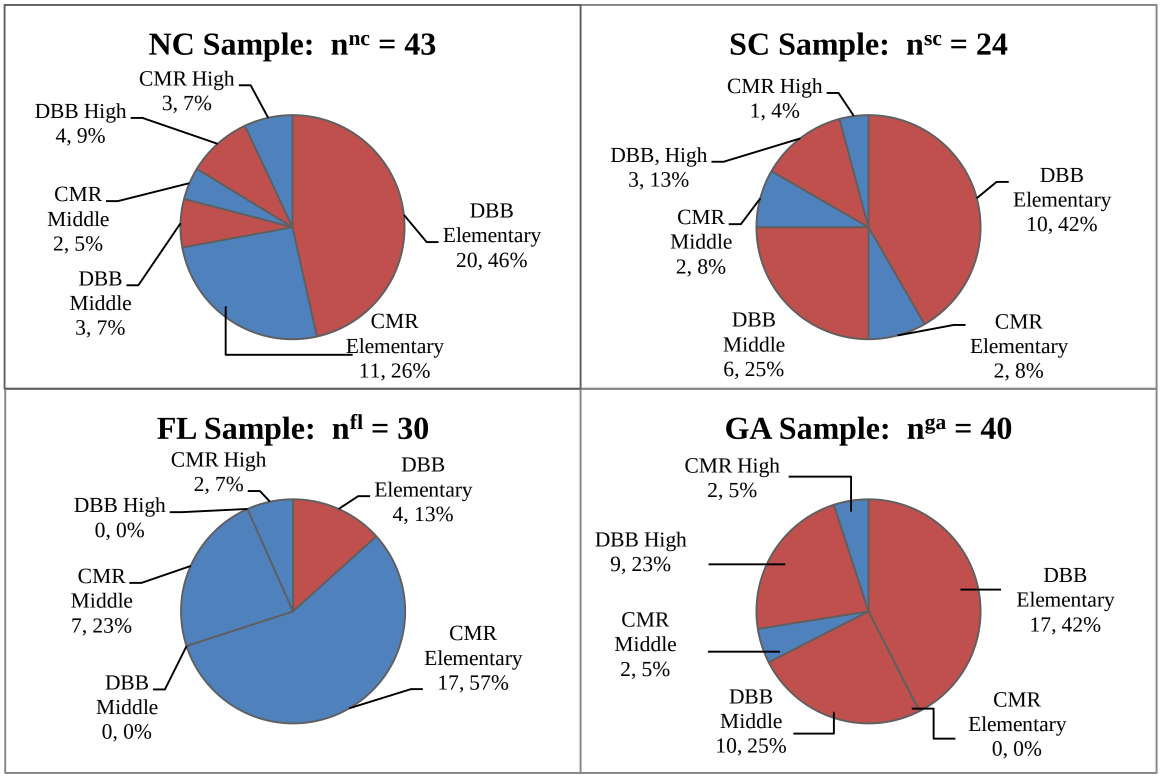


Figure 5.8 Sample Distribution by Project Delivery Method, Project Type, and State

However, the relatively large number of Elementary projects included in the North Carolina sample at 31, coupled with a relatively even distribution by project delivery methods of 11 CM at-Risk and 20 Design-Bid-Build made comparison viable at this level with regard to Elementary schools. Note however, that the smaller numbers of projects included within the North Carolina Middle and High categories increased the difficulty for viable analysis at this level. Similarly, the Florida Elementary school sample technically contained a viable number of projects for statistical comparison. However, the small sample size coupled with the wide disparity between the number of CM at-Risk

Elementary projects at 17 and the 4 completed with Design-Bid-Build serve to challenge the ability for viable analysis.

5.4.8 Implications of Sample Distributions

As described in the sections above, analysis of the sample at different levels impacts the ability of the testing procedures. Distribution of the sample into multiple levels reduces the numbers and ratios of the different projects analyzed within each category, which diminishes the power of the t-testing procedures to detect statistically significant differences between the project performance measures. In order to simplify the discussion and improve understanding for the reader, the presentation of analytical results of the historical project data presented in the next sections will be delivered on two levels as described below:

- **Primary Findings** - obtained through analysis of the sample distributed by
    - Project Delivery Method
    - Project Delivery Method and Project Type
    - Project Delivery Method and State for North Carolina and South Carolina
    - Project Delivery Method, Project Type, and State for North Carolina Elementary schools only
- **Secondary Findings -** obtained through analysis of the sample distributed by
    - Project Delivery Method and State for Florida and Georgia
    - Project Delivery Method, Project Type, and State for all states except North Carolina

5.5 Historical Data Analysis

5.5.1 Testing Procedures

Hypothesis tests and statistical evaluations were completed utilizing two group t-tests and chi-square (x^2) distributions. All testing procedures were carried out based on a 95% confidence interval utilizing SAS 9.3 (Statistical Analysis System) software. Based on the results obtained from these testing methods, use of regression analysis was not deemed to be warranted. More than 600 individual tests were completed to compare the public school projects utilizing cost, schedule, size, capacity, and quality metrics.

Initial comparisons began with t-testing of the mean values of all CM at-Risk cost, schedule, size, and capacity variables against the mean values of all corresponding Design-Bid-Build variables. Additional testing was conducted for each variable individually by State (Florida, Georgia, North Carolina, and South Carolina) and by Project Type (Elementary, Middle, and High), and by all possible combinations of State and Type. Supplementary testing was completed utilizing the creation of Size and Age variables in an attempt to examine differences in school projects related to their magnitudes of cost and duration. The Size variable was created by separating all projects into two categories based on their Final Construction Cost being either "less than and equal to" or "greater than" the median Final Construction Cost. The Age variable was created by separating all projects into two categories based on their Construction Factor Year being "less than and equal to" or "greater than" the median year. Additional testing by Size and Age revealed no significant differences among the results.

5.5.2 Project Size (Gross SF)

Primary Findings: The analysis revealed no statistically significant Project Size difference between CM at-Risk and Design-Bid-Build school projects in terms of Gross SF when comparison was made by project delivery method as shown in Figure 5.9. The

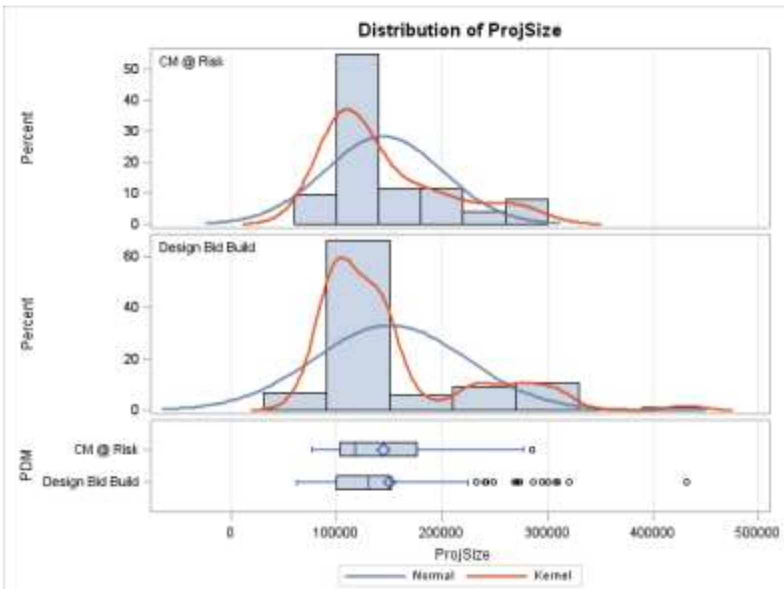


Figure 5.9 Testing of Project Size by Project Delivery Method

mean Gross SF size of CM at-Risk projects at 144,094 SF was 6,601 SF smaller than those of Design-Bid-Build at 150,695 SF. Comparison of the Project Size medians revealed similar results with CM at-Risk projects being 12,863 Gross SF smaller.

Additional testing by project type revealed no statistically significant Project Size differences. The mean Gross SF size of CM at-Risk Elementary schools was 757.5 SF smaller, the CM at-Risk Middle school mean was 19,792 SF larger, and for High schools the CM at-Risk mean was 50,553 SF smaller. The project size difference experienced with CM at-Risk Middle schools can partially be explained due to the inclusion of the K-8 schools in the Florida Middle school sample. Further testing completed without inclusion of K-8 school data revealed that the mean CM at-Risk Middle school Gross SF Size difference dropped by 155 SF to 19,637 SF. Neither of the comparisons resulted in a statistically significant difference. Additionally, although the High school mean

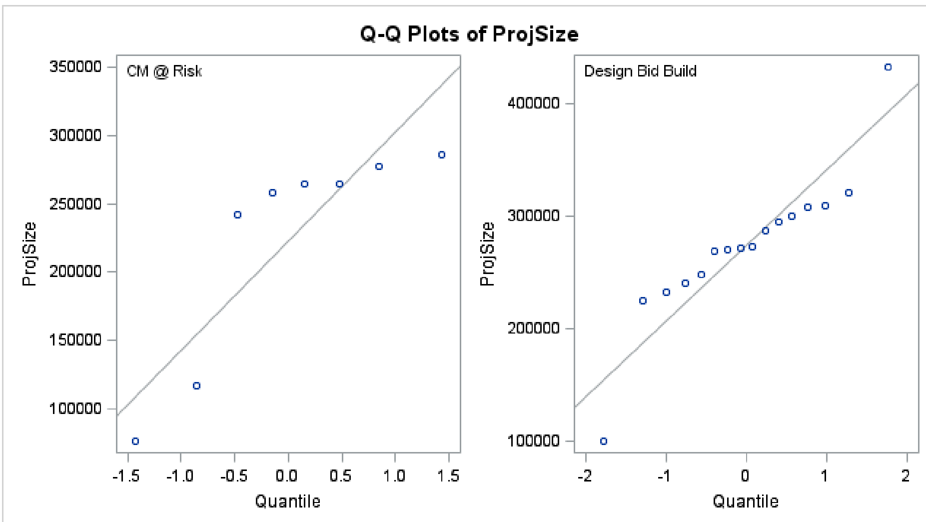


Figure 5.10 Testing of High School Project Size

difference was not statistically significant, an investigation of the cause of the wide disparity revealed that two relatively small CM at-Risk projects, one relatively small Design-Bid-Build project, and one relatively large Design-Bid-Build project were included in the High school sample as shown in Figure 5.10. Analysis of the median Gross SF of CM at-Risk High projects at 261,187 and Design-Bid-Build projects at 272,464 produced a median difference of only 11,277 SF.

Testing by state revealed no statistically significant results. North Carolina CM at-Risk schools were 18,524.3 SF larger, and South Carolina CM at-Risk schools were 20,524.6 SF smaller.

Statistically significant results were not obtained during testing by delivery method, project type, and state combined.

Secondary Findings: Testing by state revealed no statistically significant results. The mean Project Size for Florida CM at-Risk schools was 17,163.3 Gross SF larger, Georgia CM at-Risk schools were 29,149.3 Gross SF larger. The Florida size differential can partially be explained by the inclusion of the K-8 projects, which was reduced to 10,814.7 Gross SF with their removal. No statistically significant results were obtained during testing by delivery method, project type, and state combined.

5.5.3 Student Capacity

Primary Findings: The analysis revealed no statistically significant Student Capacity difference between CM at-Risk and Design-Bid-Build projects when comparison was completed by delivery method. The mean CM at-Risk Student Capacity of 1,041.8 students was almost 32 students fewer than that of Design-Bid-Build projects.

Testing by project type revealed that CM at-Risk Middle schools had significantly larger Student Capacities with a mean difference of 213.1 students and a p-value of 0.0421. However, the difference dropped to 121.6 students, not statistically significant, when the K-8 projects were removed.

Statistically significant results were not obtained during testing by state for North and South Carolina projects nor when testing for delivery method, project type, and state combined.

Secondary Findings: Additional testing by state revealed that Florida CM at-Risk projects had significantly larger Student Capacities with a mean difference of 153 students and a p-value of 0.0259. However, the difference was reduced to 72 students, not statistically significant, with the removal of the K-8 projects.

When testing by project delivery method, project type, and state combined, only North Carolina High projects showed a statistically significant difference with 1,887.7 students for CM at-Risk vs. 1556.5 for Design-Bid-Build. The mean difference was 331.2 and the p-value was 0.0386.

5.5.4 Square Foot (SF) per Student

Primary Findings: The project metric Square Foot per Student was created utilizing the Gross SF area and Student Capacity data collected from each project. Results of the analysis of this metric revealed no statistically significant difference between the CM at-Risk and Design-Bid-Build project means at 141.4 and 139.2 SF per Student respectively when tested by delivery method. Removal of the K-8 projects marginally increased the difference in means from 2.18 to 4.16 SF per Student.

Testing by project type revealed that the CM at-Risk Middle school mean was 7.89 SF per Student smaller than Design-Bid-Build, but this difference was reversed with

CM at-Risk being slightly larger, 2.21 SF per Student, with the removal of the K-8 schools.

When examined by state, the only notable difference was seen in South Carolina with CM at-Risk schools being 35.36 SF per Student larger. This difference was not statistically significant.

Secondary Findings:

Significant differences were not obtained during testing of SF per Student by state in Florida or Georgia or by project delivery method, project type, and state combined.

5.5.5 Normalization of Cost Data

Prior to conducting the analysis, all costs were normalized to 2012 US dollars utilizing historical cost indexes and methods provided by RS Means (2013). For verification purposes, costs were factored and tested utilizing two individual methods. First, all costs were normalized utilizing RS Means in order to "estimate and compare construction costs in different cities for different years" (RS Means, 2013, p. 459). Cost variables for all projects were then normalized to a 2012, Charlotte, North Carolina location prior to being statistically analyzed. (Cost estimates for 2012, Charlotte Public Schools are provided in Appendix I. Median public school costs published by School Planning and Management, 2013 are provided in Appendix J.) As a verification procedure, a Region Average was created to mirror the RS Means National 30 City Average. The Region Average included all cities listed in RS Means for the 4 state study area (Florida, Georgia, North Carolina, and South Carolina) plus Chattanooga, Tennessee and Mobile, Alabama. These 2 cities were added to the Region Average due to projects that were constructed within the study area, but were located in close proximity to these out of state cities. Cost performance variables for all projects were then normalized utilizing the 2012 Region Average and a separate round statistical analysis was conducted.

A detailed comparison of the results obtained through analysis of both sets of normalized data was conducted. Although factored cost variables utilizing the Region Average proved to be marginally higher than those factored utilizing the Charlotte Factor, cost increases were relative across both the CM at-Risk and Design-Bid-Build school projects. The comparative analysis revealed virtually no differences in the performance variable test results, whether costs were factored by the 2012 Charlotte Factor or the 2012 Region Average. For the purpose of this study, all costs utilized and reported throughout the analysis were those obtained employing the Charlotte Factor normalization procedure.

A complete report of the SAS data analysis of conducted at the project delivery level including means, differences, standard deviations, and confidence limits for cost and schedule performance metrics discussed throughout the data analysis sections is provided in Appendix K.

5.5.6 Construction Cost

Primary Findings: The analysis indicated that CM at-Risk projects had significantly higher costs in terms of the Original Construction Cost and Final Construction Cost when comparisons were made by project delivery method. The mean Original Construction Cost for CM at-Risk projects was $26,001,207, which was $5,040,740, 24.0% higher (p-value 0.0148) than the mean of $20,960,467 for Design-Bid-Build projects. The mean Final Construction Cost for CM at-Risk projects was $26,101,221, which was $4,820,935, 22.7% higher (p-value 0.0230) than Design-Bid-Build at $21,280,286.

Note: a summary of the construction and project cost analysis is provided in Figure 5.14, page 114.

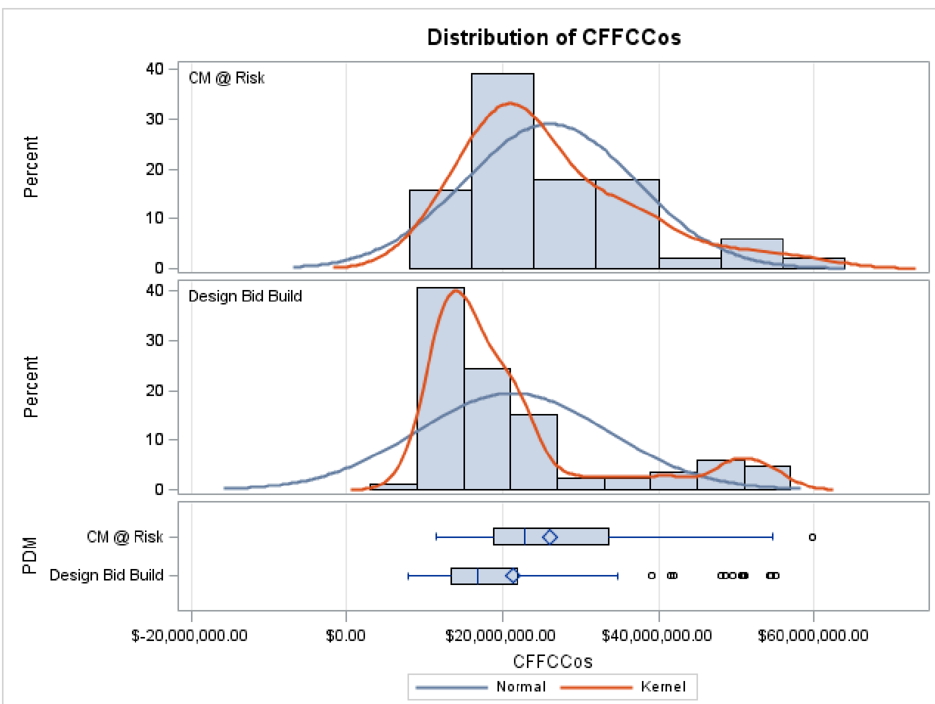


Figure 5.11 Testing of Final Construction Cost by Project Delivery Method

Additional testing by project type revealed that means for Construction Cost were significantly higher for CM at-Risk Elementary projects, having a mean difference of $4,707,176, 31.0%, with a p-value less than 0.0001, and CM at-Risk Middle schools, having a mean difference of $12,396,328, 65.7%, with p-value less than 0.0001.

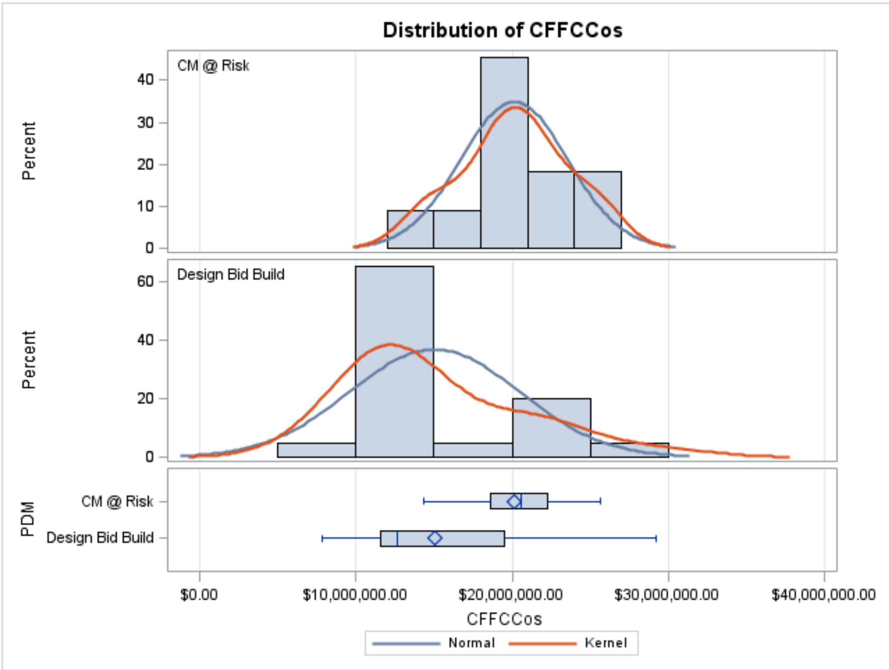


Figure 5.12 Testing of Final Construction Cost by North Carolina Elementary Schools

Note that the mean difference for Middle schools was reduced to $12,136,273, 63.5%, with p-value of 0.0029, after removal of the K-8 schools. The mean Final Construction Cost of CM at-Risk High schools was lower than that of Design-Bid-Build, with a mean difference of $2,582,749, 5.9%. However, with a p-value of 0.6103, the difference was not significant. Note that the previously presented mean Project Size of CM at-Risk High schools revealed that these schools were 50,553 square feet smaller than their Design-

Bid-Build counterparts, which accounts for the lower Construction Cost. Furthermore, as presented in an upcoming section, the CM at-Risk High schools were shown to have a mean Unit Cost that was $25.48 per square foot higher than that of Design-Bid-Build.

Testing by state revealed that means for Construction Cost performance metrics were higher for CM at-Risk projects across both North and South Carolina, although, a statistically significant difference was obtained only in North Carolina. The mean difference was $8,932,103, 46.6%, higher for CM at-Risk, with a p-value of 0.0248. In South Carolina, the CM at-Risk mean was only $382,505 higher.

Further testing by delivery method, project type, and state combined revealed that the mean Final Construction Cost of North Carolina Elementary schools constructed utilizing CM at-Risk was $20,145,201, which was $5,113,654, 34.0%, higher (p-value 0.0087) than the mean value of those constructed utilizing Design-Bid-Build.

Secondary Findings: Testing by state revealed that means for Construction Cost performance metrics were higher for CM at-Risk projects in Florida and Georgia, although, a significant difference was obtained only in Florida. The mean difference was $6,548,503, 35.3%, higher for CM at-Risk with a p-value of 0.0064. Note that the mean difference in Florida was reduced to $5,324,023, but remained significantly higher, with p-value of 0.0356, after the K-8 schools were removed for testing. The mean Final Construction Cost of Georgia CM at-Risk projects was shown to be higher than Design-Bid-Build by $6,574,564.

South Carolina Elementary and Middle and North Carolina Middle schools constructed with CM at-Risk were shown to have significantly higher means for Construction Cost. The mean for South Carolina Elementary schools constructed utilizing CM at-Risk was $20,885,365, which was $6,001,571, 40.3%, higher (p-value 0.0008) than the mean value of those constructed utilizing the Design-Bid-Build method. The mean for South Carolina Middle schools utilizing CM at-Risk was $27,288,797, which was $7,466,635, 37.7%, higher (p-value 0.0213) than the mean value of those constructed utilizing the Design-Bid-Build method. The North Carolina Middle school mean difference was shown to be $18,438,803, *107%*, higher for CM at-Risk schools with a p-value of 0.0055, which seemed rather implausible. However, although a close examination of the data revealed that there were only 2 CM at-Risk and 3 Design-Bid-Build projects in the sample, the projects were similar in square footage and student capacity (CM at-Risk marginally larger), and were designed and constructed during the same time period (2008-2012). An examination of the unit cost and student cost means revealed that the CM at-Risk schools were higher by $68.69, 56.5%, per square foot and $11,078.20, 63.1%, per student.

5.5.7 Design Cost

Primary Findings: Testing revealed that there was no statistically significant difference between the mean Design Cost of CM at-Risk school projects and that of Design-Bid-Build projects when comparison was made by project delivery method. The mean Original Design Cost for CM at-Risk school projects was $1,139,885 as compared to $1,062,762 for Design-Bid-Build for a difference of $77,123, 7.3%. The mean Final

Design Cost for CM at-Risk was shown to be $187,808, 16.4%, higher than that of Design-Bid-Build at $1,147,268.

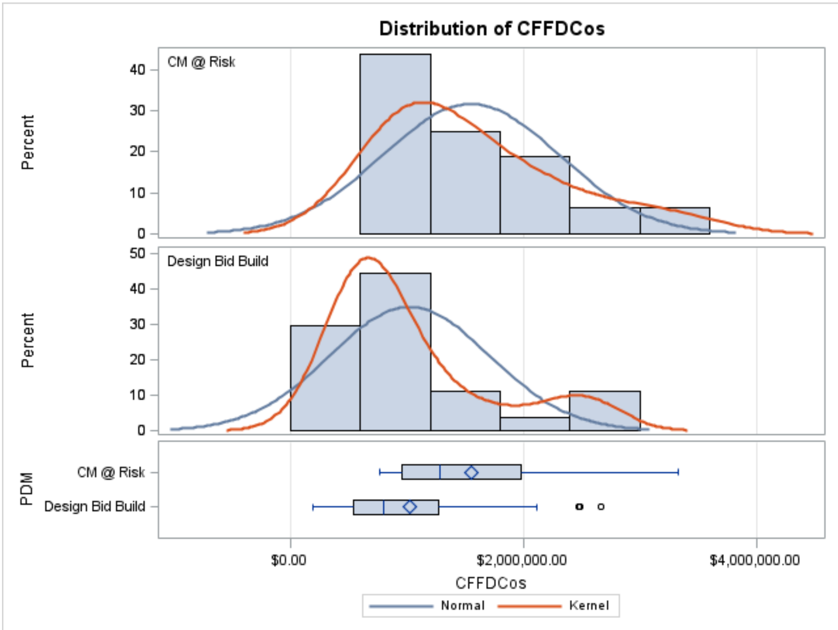


Figure 5.13 Testing of Final Design Cost by North Carolina

When viewed by state, North Carolina projects were shown to have a significantly higher mean Final Design Cost. The mean for CM at-Risk projects was $1,549,367, whereas Design-Bid-Build was $1,022,919, for a difference of $526,448, 51.5% more with a p-value of 0.024. This can primarily be explained by the fact that design fees are most often based on a percentage of the construction cost. Since the mean Construction Cost was shown to be significantly higher for North Carolina CM at-Risk projects, it follows that Design Costs for CM at-Risk projects would be higher as well.

Analysis conducted by project type revealed means for Final Design Cost of CM at-Risk Elementary and Middle school projects were significantly higher than those of

Design-Bid-Build projects. The mean Final Design Cost of CM at-Risk Elementary schools was \$1,051,081, which was \$269,918, 34.6%, higher than that of Design-Bid-Build, p-value less than 0.0001. For Middle schools, the mean difference was \$548,440, 54%, higher for CM at-Risk with a Final Design Cost of \$1,558,850 and a p-value of 0.0003. A statistically significant difference was not seen with High schools projects.

Testing conducted by delivery method, project type, and state combined revealed a statistically significant difference in the mean Final Design Cost of North Carolina Elementary projects. Those constructed with the CM at-Risk method had a mean of \$1,123,411 compared to \$718,349 for Design-Bid-Build. The mean difference of \$405,062, 56.4%, was significantly higher for CM at-Risk projects, p-value of 0.0010.

Additionally, per the previously discussed cost information regarding dissimilar reporting of reimbursable fees, individual testing revealed no statistically significant differences for reimbursable costs of these projects. Furthermore, since the cost of Design Fees was the only difference between the variables of Construction Cost and Project Cost, any differences detected while testing variables related to Construction Cost directly correlated when testing variables related to Project Cost.

Secondary Findings: No statistically significant results were obtained during testing of the secondary levels of distribution.

5.5.8 Project Cost

Primary Findings: The analysis indicated that CM at-Risk projects had significantly higher costs in terms of the Original Project Cost and Final Project Cost when comparisons were made by project delivery method. The mean Original Project Cost for CM at-Risk projects was $27,141,092, which was $5,117,863, 23.2%, higher (p-value 0.0180) than the mean of $22,023,229 for Design-Bid-Build. The mean Final Project Cost for CM at-Risk projects was $27,436,298, which was $5,008,743, 22.3%, higher (p-value 0.0250) than the mean of $22,427,554 for Design-Bid-Build. Note that testing of the Project Cost metrics has confirmed that Design Cost similarity discussed in the next section causes Project Cost to directly correlate with Construction Cost.

Testing by project type revealed that means for Project Cost were significantly higher for CM at-Risk Elementary projects having a mean difference of $4,977,094, 31.2%, with a p-value less than 0.0001, and CM at-Risk Middle schools having a mean difference of $12,944,768, 65.1%, with p-value less than 0.0001. Note that the mean difference for Middle schools was reduced to $12,584,570, 63.3%, with p-value of 0.0029 *after* removal of the K-8 schools. The mean Final Project Cost of CM at-Risk High schools was $3,023,070, 6.6%, lower than that of Design-Bid-Build. However, with a p-value of 0.6103, the difference was not significant. Furthermore, due to the previously described smaller mean Project Size, these schools were shown to have a higher Unit Cost as will be described in the following section.

Testing by state revealed that means for Project Cost performance metrics were higher for CM at-Risk projects. A statistically significant difference was obtained in North Carolina, where the mean difference was $9,458,551, 46.8%, higher, with a p-value of 0.0243. In South Carolina, the CM at-Risk mean exceeded that of Design-Bid-Build by only $269,093.

Further testing by delivery method, project type, and state combined revealed that the mean Final Project Cost of North Carolina Elementary schools constructed utilizing CM at-Risk was $21,268,612, which was significantly higher than the mean of Design-Bid-Build projects by $5,518,716, 35.4%, with a p-value of 0.0069.

Secondary Findings: In Florida, the Final Project Cost mean difference was significantly higher for CM at-Risk by $6,674,837, 33.9%, with a p-value of 0.0081. The mean was reduced to $5,351,032, but remained significantly higher, with a p-value of 0.0433, after removal of the K-8 projects. The mean Final Project Cost of Georgia CM at-Risk projects was higher than Design-Bid-Build by $6,715,631.

Testing by delivery method, project type, and state combined revealed that South Carolina Elementary and Middle and North Carolina Middle schools constructed with CM at-Risk were shown to have significantly higher means for Project Cost. The CM at-Risk Project Cost mean for the Elementary schools was $21,912,963, which was $6,197,297, 39.4%, higher (p-value 0.0010) than the mean value of Design-Bid-Build. The mean for South Carolina Middle schools utilizing CM at-Risk was $28,920,069, which was $8,047,826, 38.6%, higher (p-value 0.0196) than those utilizing Design-Bid-Build. Additionally, the North Carolina Middle school mean difference was $19,243,211, 105%, higher than that of Design-Bid-Build, with a p-value of 0.0059. This extremely high difference was supported by a close inspection of the data, unit costs, and student costs.

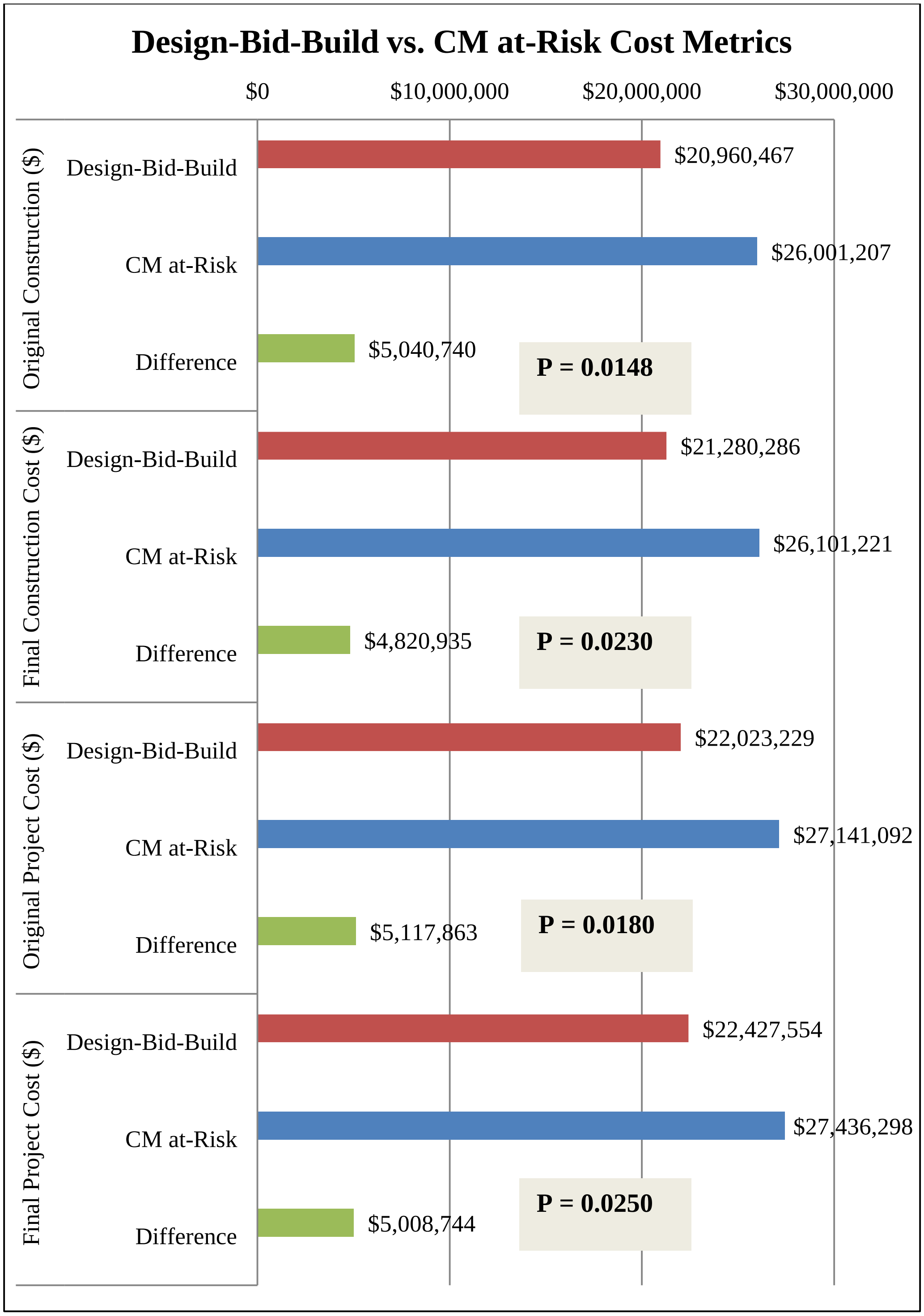


Figure 5.14 Construction and Project Costs by Project Delivery Method

5.5.9 Unit Cost

Primary Findings: The analysis indicated that CM at-Risk school projects had a significantly higher mean Unit Cost when comparison was made by project delivery method. The mean Unit Cost for CM at-Risk projects was shown to be \$191.60, which was \$42.80, 28.9%, per Gross SF higher (p-value less than 0.0001) than for Design-Bid-Build projects at \$148.80.

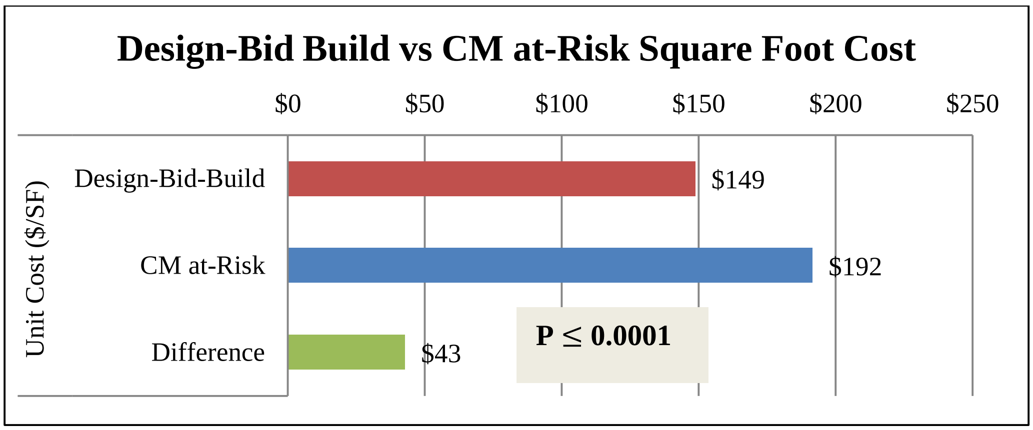


Figure 5.15 Testing of Unit Cost by Project Delivery Method

A statistically significant difference in the Unit Cost for Elementary schools was also noted. The mean Unit Cost for CM at-Risk Elementary schools was \$191.8 as compared to \$148.0 for Design-Bid-Build making the mean difference \$43.87, 29.6%, higher per Gross SF, with a p-value less than 0.0001. CM at-Risk Middle schools were also higher with a difference of \$55.22, 41.1% per Gross SF over Design-Bid-Build with a p-value of 0.0004. The mean Unit Cost for Middle schools constructed with the CM at-Risk method was \$189.6 as opposed to \$134.3 for Design-Bid-Build. Note that the difference in the CM at-Risk Middle school Unit Cost can partially be explained by the inclusion of the K-8 schools. Removal of these projects dropped the difference to $50.79, but the difference remained significant, with a p-value of 0.0020. CM at-Risk High schools were shown to have a mean Unit Cost of $194.05 per square foot, which was $25.48 per square foot higher than Design-Bid-Build at $168.56, although the difference was marginally insignificant, having a p-value of only 0.0543.

Additional testing by state revealed a significant Unit Cost difference for both North and South Carolina. The mean difference in North Carolina was $46.90, 29.4%, higher per Gross SF, with a p-value of 0.0002. CM at-Risk projects had a mean Unit Cost of $206.60 compared to $159.70 for Design-Bid-Build. The Unit Cost for South Carolina CM at-Risk projects was $205.80 as compared to that of $168.20 for Design-Bid-Build. The mean difference was $37.60, 22.4%, higher per Gross SF with a p-value of 0.0136.

Analysis by project type, state, and project delivery method combined revealed a significant difference in the Unit Cost mean for North Carolina Elementary schools. The CM at-Risk projects had a mean Unit Cost of $209.4 compared to $162.6 for Design-Bid-Build for a mean difference of $46.85, 28.8%, higher per square foot, p-value of 0.0096.

Secondary Findings: Analysis of North Carolina Middle and South Carolina Elementary schools also revealed significantly higher means for Unit Cost. The Unit Cost for South Carolina Elementary CM at-Risk projects was $211.3 as compared to that of Design-Bid-Build with $164.7 for a mean difference of $46.52, 28.2%, more per square foot, with a p-value of 0.017. The North Carolina Middle school CM at-Risk mean Unit Cost was $190.30 as compared to $121.60 for Design-Bid-Build providing a difference of $68.69, 56.5%, more per square foot, with a p-value of 0.0137.

5.5.10 Student Cost

Primary Findings: The analysis indicated that CM at-Risk schools had a significantly higher mean Student Cost when comparison was made by project delivery method.

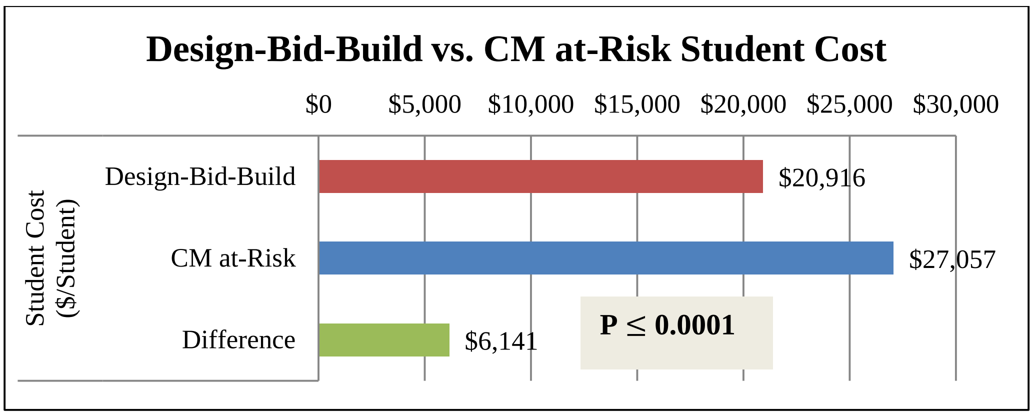


Figure 5.16 Testing of Student Cost by Project Delivery Method

The mean Student Cost for CM at-Risk projects at $27,057.00 was $6,141.40, 29.4%, higher per student than Design-Bid-Build at $20,915.60. The p-value was less than 0.0001.

Testing by project type revealed a statistically significant difference in the mean Student Cost for Elementary schools, which showed a mean difference of $6,897.30, 36.4%, higher per student for the CM at-Risk method, with a p-value less than 0.0001.

The mean Student Cost for CM at-Risk Elementary projects was \$25,843.90 per student and Design-Bid-Build was \$18,946.60. A statistically significant difference was also obtained with analysis of Middle schools, with CM at-Risk projects being \$7,000.8, 35.6%, higher per student, with a p-value of 0.0095. For CM at-Risk Middle schools, the mean Student Cost was \$26,652.6 per student vs. \$19,651.7 for Design-Bid-Build. The Middle school difference in means rose to \$8,561.4 per student remaining significantly higher, with a p-value of 0.0014 when the Florida K-8 schools were removed. CM at-Risk High schools were shown to have a mean Student Cost of \$32,263.60, which was \$3,570.70 per student higher than Design-Bid-Build at \$28,692.90. The difference was not statistically significant.

Additional testing by state revealed a statistically significant difference of \$5,675.80 in the mean Student Cost for North Carolina projects with a p-value of 0.0205. The mean Student Cost for CM at-Risk projects was 25.9% higher at \$27,563.20 per student as compared to the mean of Design-Bid-Build at \$21,887.40. In South Carolina, the Student Cost was also shown to be significantly higher for CM at-Risk projects having a mean difference of \$12,657.0, 52.5%, more per student, with a p-value of 0.0050. The mean Student Cost for projects constructed with the CM at-Risk method in that state was \$36,763.0 per student vs. \$24,105.9 constructed with Design-Bid-Build.

Similar to the Unit Cost analysis, testing by project type, state, and delivery method combined provided a statistically significant difference in North Carolina Elementary Student Cost means. The CM at-Risk mean Student Cost was \$26,784.90 compared to \$21,338.10 for Design-Bid-Build. The mean difference was \$5,446.80, 25.5%, per student higher, with a p-value of 0.038.

Secondary Findings: North Carolina Middle and South Carolina Elementary schools constructed with the CM at-Risk method also had significantly higher means for Student Cost. The North Carolina Middle CM at-Risk mean Student Cost was $28,627.40 per student compared to $17,549.20 for Design-Bid-Build providing a difference of $11,078.20, 63.1%, higher per student, with a p-value of 0.0025. Elementary projects constructed with CM at-Risk in South Carolina had a mean Student Cost of $31,118.80 vs. $20,559.20 for a difference of $10,559.60, 51.4% per student with a p-value of 0.0268.

5.5.11 Cost Growth %

Primary Findings: The analysis indicated that Cost Growth on CM at-Risk school projects was not significantly different from the Cost Growth on Design-Bid-Build school projects when comparison was made by project delivery method. The mean Construction Cost Growth for CM at-Risk projects was 0.32%, which was 0.94% less than the 1.25% of Design-Bid- Build projects. Similarly, Project Cost Growth for CM at-Risk schools was 1.04%, which was 0.41% less than the 1.45% of Design-Bid-Build projects.

Secondary Findings: Additional testing by project type, state, and project type, state, and delivery method combined revealed no statistically significant differences other than with Georgia High schools. The mean Construction Cost Growth for Georgia CM at-

Risk High projects was -3.36% for a difference of 4.43% lower than that of Design-Bid-Build at 1.07%. The p-value was 0.0046.

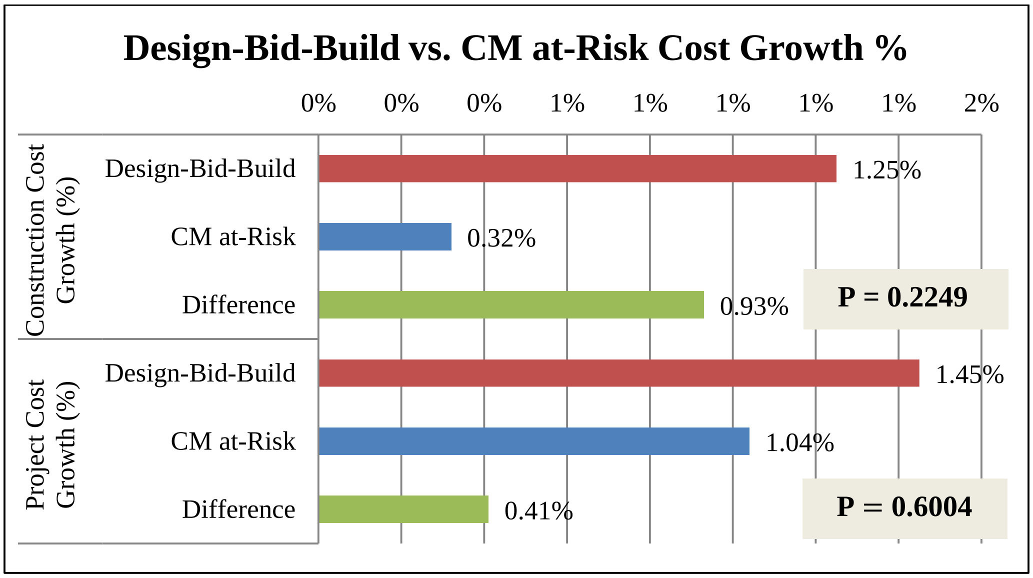


Figure 5.17 Testing of Project Cost Growth by Project Delivery Method

5.5.12 Schedule Duration (Days)

Primary Findings: The analysis indicated that there were no statistically significant differences between CM at-Risk and Design-Bid-Build school projects with regard to Construction or Project Schedule metrics when comparisons were made by project delivery method. The mean Actual Construction duration for CM at-Risk school projects at 564.7 days was 4.33 days, 0.76% shorter than the mean of 569.0 days for Design-Bid-Build. The mean Actual Project duration for CM at-Risk schools at 1,008.3 days was 15.30 days, 1.49% shorter than the Design-Bid-Build project mean at 1,023.6 days.

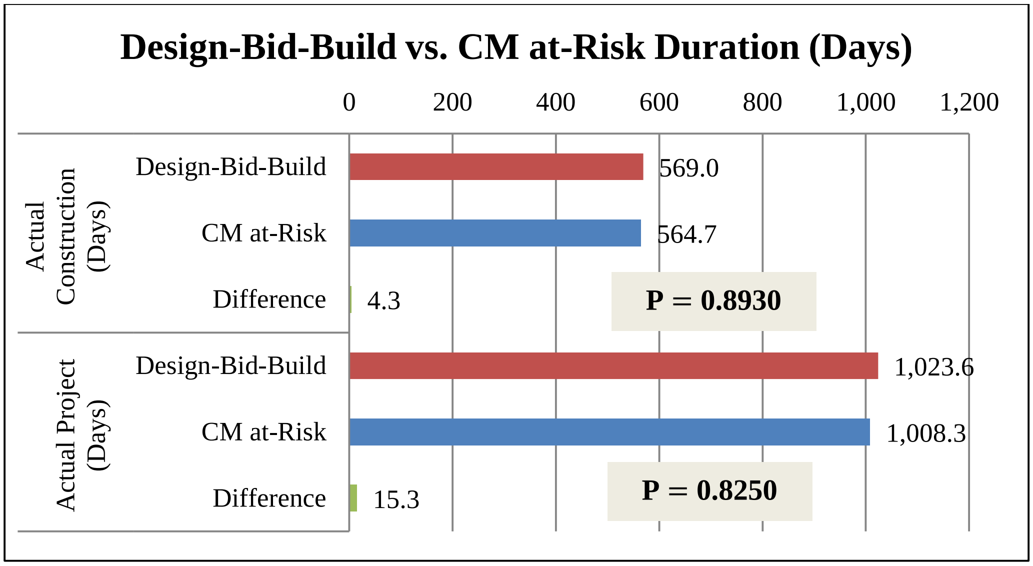


Figure 5.18 Testing of Actual Construction and Project Duration by Project Delivery Method

There were no significantly different results when project schedule metrics were analyzed by project type and the results were mixed. The mean Actual Construction duration for CM at-Risk Elementary projects was 470.3 days vs. 508.4 days for Elementary projects constructed utilizing the Design-Bid-Build method for a difference of 38.15, 7.5%, fewer days for CM at-Risk. For Middle schools, the mean Actual Construction duration was 627.0 days for CM at-Risk projects as opposed to 598.7 days for those constructed with Design-Bid-Build for a difference of 28.32, 4.7%, days longer for CM at-Risk. Likewise, for High schools, the mean Actual Construction duration was 817.6 days for CM at-Risk projects compared to 727.1 days for Design-Bid-Build for a difference of 90.56, 12.5%, more days for CM at-Risk.

Analysis of projects in both North and South Carolina showed that projects constructed with the CM at-Risk method had longer Actual Construction durations by

28.94 and 71.76 days respectively. Neither of these differences was statistically significant. Analysis by project type, state, and delivery method combined provided no statistically significant differences.

Secondary Findings: Georgia was the only state in which a statistically significant difference was found. The Georgia mean Actual Construction duration was 240.8 days, 39.7%, longer for CM at-Risk projects, with a p-value of 0.0283. The CM at-Risk school projects had a mean of 847.5 days vs. 606.7 days for projects constructed utilizing the Design-Bid-Build method. An examination of the data revealed that the 4 CM at-Risk projects compared to the 36 Design-Bid-Build projects included in the sample were 2 High and 2 Middle school projects. Middle and High projects are larger and tend to have longer durations. Conversely, Florida schools constructed utilizing the CM at-Risk method had a mean Actual Construction duration of 507.3 days compared to that of Design-Bid-Build with 531.3 days for a mean difference of 23.98, 4.51%, fewer days. An examination of the Florida sample revealed that the 4 Design-Bid-Build projects compared to the 17 CM at-Risk projects included in the sample were all Elementary schools, which tend to be smaller and thus, of shorter duration.

5.5.13 Schedule Growth %

Primary Findings: The analysis indicated that there were no statistically significant differences between CM at-Risk and Design-Bid-Build school projects with regard to the Project or Construction Schedule Growth metrics when comparisons were made by project delivery method. The mean Construction Schedule Growth for CM at-Risk school projects was 12.41% as compared to 15.58% mean Growth for projects constructed with the Design-Bid-Build method. The mean difference was 3.17%, which was 20.3% lower in favor of CM at-Risk. The mean Project Schedule Growth for CM at-Risk school projects was 6.52% as compared to 8.11% mean for projects constructed with the Design-Bid-Build method. The mean difference was 1.60%, which was 19.7% less in favor of CM at-Risk. Additional testing by project type, state, and project type, state, and delivery method combined revealed no statistically significant differences for either primary or secondary levels of distribution.

Although analysis of the Construction Schedule duration did not reveal statistically significant results when comparison was based on project delivery method, additional examination of the data did reveal important findings of interest. Typically, construction schedule overruns are discussed in terms of the number of days or the percentages of time that projects run beyond their contractual completion dates. However, since the originally *contracted* completion dates are frequently altered by the additions of time (days) added to the schedule in the form of change orders, projects are often completed contractually "on time" even though they run well beyond the originally *intended/predicted* completion date. Projects that are completed contractually "on time" are not necessarily the same as those that are completed to meet the *intended* owner deadline as *predicted* by the contractor. This is an important distinction and should be of primary importance for district construction managers and other decision makers that base their project delivery method selections in large part on the ability of the delivery method to predict and control the construction schedule.

The top section of Figure 5.19 presents the previously discussed Construction Schedule Growth of school projects completed with the CM at-Risk delivery method compared with those completed utilizing Design-Bid-Build along with the mean difference of 3.17%. Construction Growth is the percentage of time growth (positive or negative) over the duration of the construction period. Specifically, Construction Growth is the percentage of construction time that the school's originally contracted end date has shifted by the time the project has reached substantial completion. This includes change orders time and any other issues that cause the project to finish beyond the date originally intended by the owner. The lower bars in the figure represent the Revised Construction Growth percentage. Revised Growth is differentiated from Construction Growth in that the percentage of time is measured from the revised contractual completion date (after change orders) to the date of substantial completion. Essentially, this is the percentage measure of how "late" projects finish beyond their contractual completion dates.

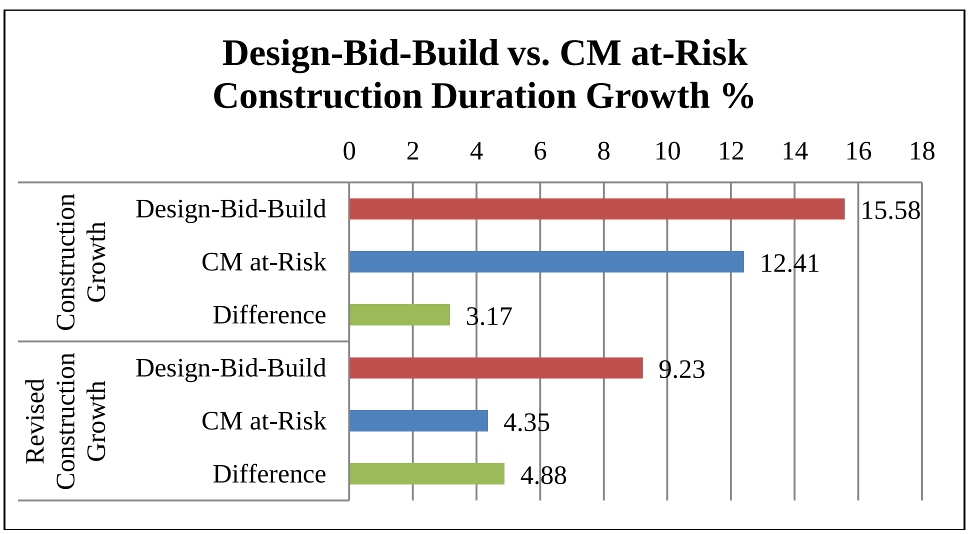


Figure 5.19 Construction Duration Growth %

Note that the mean difference between the percentage of CM at-Risk and Design-Bid-Build was 4.88 percent, meaning a 53% lower mean for CM at-Risk. The evidence appeared to support that the CM at-Risk method was performing at a better level than Design-Bid-Build in the area of schedule control.

However, on further examination there was evidence to show that the differences noted above may have had less to do with schedule control than they did with change order approval and proper accounting for time. As presented in Figure 5.20, the Planned Duration for the CM at-Risk projects shown on the top line of the figure was marginally longer (13.7 days) than that of Design-Bid-Build. A review of the Revised Duration shown in the middle section reveals that the difference grew from 13.7 days to 21.4 days. This appears to show that the CM at-Risk projects received longer or more extensions of

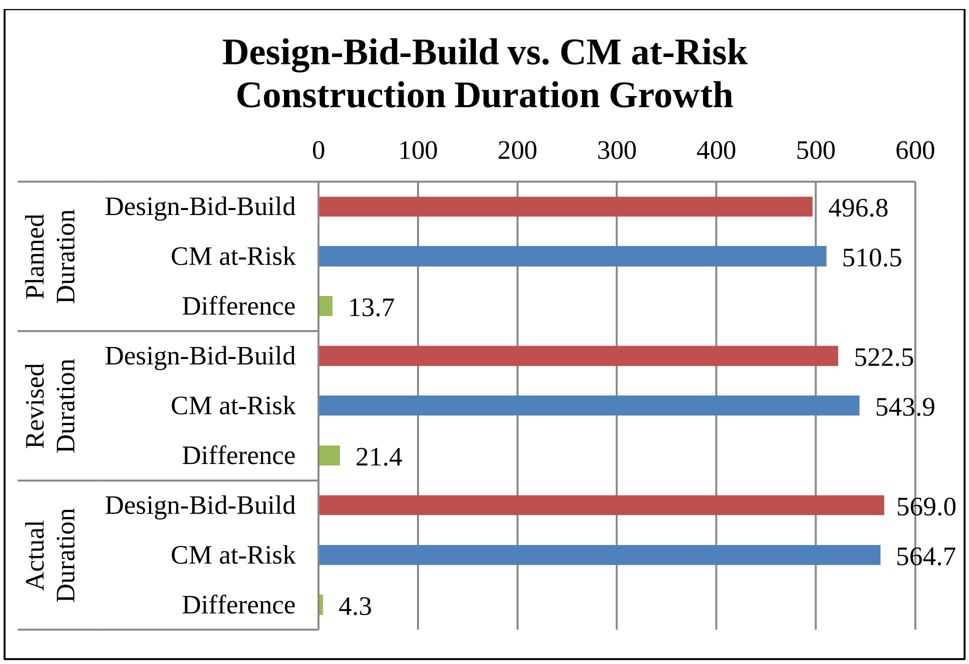


Figure 5.20 Construction Duration Growth (Days)

time (7.7 days more) than did Design-Bid-Build projects. Furthermore, the figure shows that CM at-Risk projects had marginally longer Planned Durations and marginally shorter Final Durations resulting in the previously discussed lower Growth percent. Although none of these differences was shown to be statistically significant, it may be evidence that the collaborative properties of the CM at-Risk method may be influencing change order durations. This issue will be discussed in the following chapter.

5.5.14 Project Intensity SF/Day

Project Intensity (SF/Day) was utilized as a measure of productivity to determine the number of square feet of public school facility constructed per project (design and construction) schedule day. As a secondary measure, tests of *Construction Intensity* (SF/Day) utilizing the construction schedule in lieu of the project schedule were conducted resulting in similar findings.

Primary Findings: The analysis indicated there were no statistically significant differences between CM at-Risk and Design-Bid-Build school projects with regard to Project Intensity SF/Day when comparisons were made by project delivery method or any other levels. The mean Project Intensity for CM at-Risk was found to be 152.6 SF/Day as compared to 158.7 SF/Day for that of Design-Bid-Build for a difference of 6.09 SF/Day less for CM at-Risk. These results were not unexpected based on the previous analysis showing no significant Size or Schedule differences. The results reduced the usefulness of the Project Intensity SF/Day metric as a measure of productivity performance. As a secondary measure, tests of *Construction Intensity*

(SF/Day) utilizing the construction schedule in lieu of the project schedule were conducted resulting in similar insignificant findings.

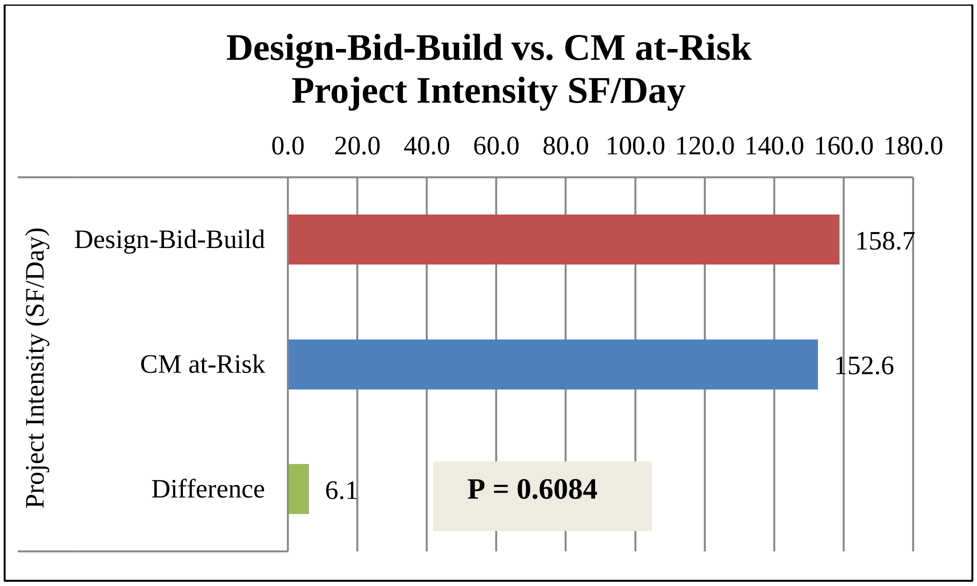


Figure 5.21 Project Intensity SF/Day

Secondary Findings: The analysis indicated there were no statistically significant differences between CM at-Risk and Design-Bid-Build school projects during testing of the secondary levels of distribution.

5.5.15 Project Intensity $/Day

Project Intensity ($/Day) was utilized as a measure of productivity to determine the amount of project cost put in place per project (design and construction) schedule day. As a secondary measure, tests of *Construction Intensity* ($/Day) utilizing the construction schedule in lieu of the project schedule were conducted resulting in similar findings.

Primary Findings: The analysis indicated there was a statistically significant difference between CM at-Risk school projects and those constructed utilizing Design-Bid-Build with regard to Project Intensity based on $/Day when comparison was made by project delivery method. The mean Project Intensity for CM at-Risk projects was $28,784.40/Day vs. $22,924.90/Day for projects completed utilizing the Design-Bid-Build method for a mean difference of $5,859.50/Day and p-value of 0.0033. The removal of the K-8 schools reduced the mean difference to $4,748.20/Day, which remained statistically significant, with a p-value of 0.0178.

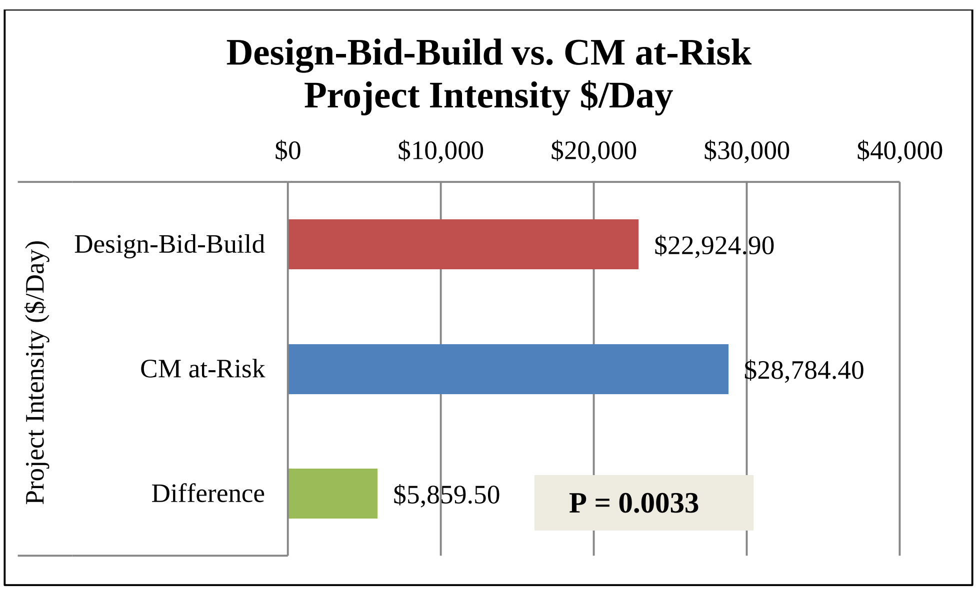


Figure 5.22 Project Intensity $/Day

Analysis by project type revealed that CM at-Risk Elementary and Middle school projects were significantly more intensive. The mean Project Intensity for CM at-Risk Elementary schools was $25,471.6 $/Day as compared to Design-Bid-Build with a mean of $18,916.3/Day for a significantly higher difference of $6,555.2/Day for CM at-Risk and a p-value of 0.0002. For Middle schools, the CM at-Risk mean Intensity was $35,298.2/Day vs. $21,430.6/Day, with CM at-Risk being significantly more intensive by $13,867.6/Day and p-value of 0.0013. The mean difference was lowered to $10,959.0/Day with the removal of the K-8 schools, but remained statistically significant with p-value of 0.0187.

Additional analysis by state did not reveal statistically significant results. However, additional analysis by project type, state, and delivery method combined revealed that only North Carolina Elementary schools projects had a statistically significant difference in Project Intensity. The CM at-Risk mean was $23,199.2/Day compared with the Design-Bid-Build mean of $17,484.8/Day for a difference of $5,714.4/Day in favor of CM at-Risk, with p-value of 0.0177.

The results noted above were expected based on the previously shown statistically significant cost differences in combination with the insignificant schedule differences. These results reduce the usefulness of the Project Cost Intensity $/Day metric as a measure of productivity performance.

Secondary Findings: No statistically significant results were obtained during testing of the secondary levels of distribution.

5.5.16 Readiness

The Readiness metric was developed from schedule data to establish the amount of time in days that was utilized by the contractor to finish all incomplete (punch list) and other miscellaneous items of work. Readiness is the measure of days between the date of Substantial Completion and the date of Final Completion.

Primary Findings: The analysis indicated there was no statistically significant difference between the mean Readiness of CM at-Risk school projects and Design-Bid-Build projects when comparison was made by project delivery method. The mean Readiness measure for CM at-Risk school projects was shown to be 312.9 days vs. 347.4 days for Design-Bid-Build with a mean difference of 34.5 days less for CM at-Risk.

Additional testing by project type revealed no statistically significant differences.

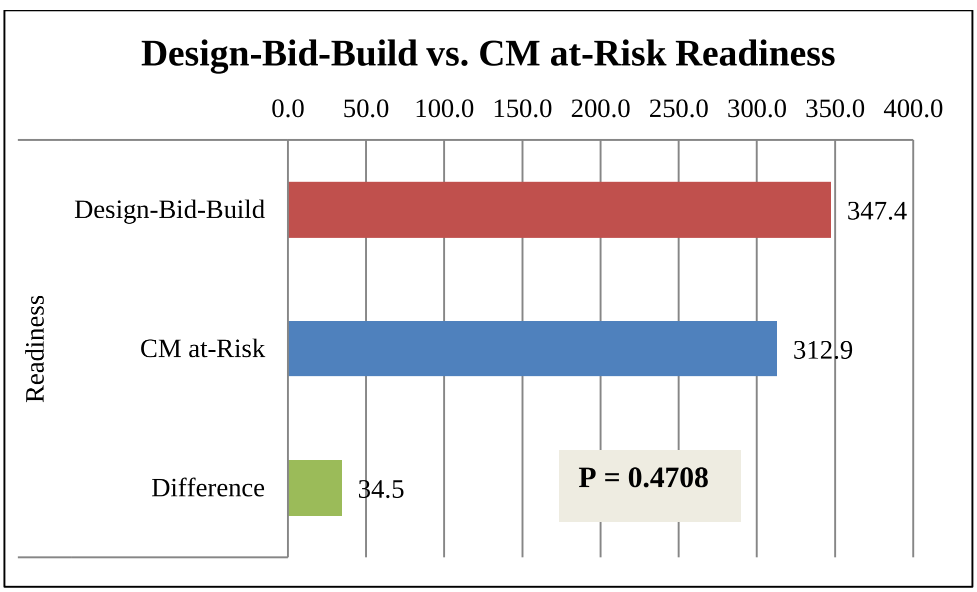


Figure 5.23 Project Readiness

Secondary Findings: Analysis by state revealed a statistically significant difference only in Florida. The CM at-Risk mean was 197.6 days compared with the Design-Bid-Build mean of 45.75 for a difference of 151.8 days higher for CM at-Risk with p-value of 0.0001. Almost identical results were obtained through analysis by project type, state, and delivery method combined with Florida Elementary schools having a mean difference of 151.0 days higher for CM at-Risk. This difference can partially be explained by evidence obtained during the research revealing that CM at-Risk projects often undergo an extensive and time-consuming auditing process following completion of the work and prior to final payment being made.

5.6 Survey Data Analysis

The survey was utilized to obtain reliable district manager perceptions of the product quality of the new facility and the quality of service provided by the construction and design teams during the design and construction process. A copy of the survey instrument is provided in Appendix B.

5.6.1 Survey Data Testing Procedures

Testing of survey questions was completed utilizing chi-square (x^2) distributions and significant statistical differences have been described when p-values were ≤ 0.05. Although the lower two survey response categories (Very Dissatisfied and Somewhat Dissatisfied, Very Unimportant and Somewhat Unimportant, and Very Ineffective and

Ineffective) were selected more often by Design-Bid-Build managers than were by CM at-Risk managers, very few responses were provided within these two lowest categories for any survey question. The limited number of responses rendered analysis of the lower categories unviable for some questions. In most cases, responses received in the lowest two categories were combined into a single category: Dissatisfied, Unimportant, or Ineffective, in order to improve the viability for statistical analysis. In cases where an adequate number of combined responses did not exist, the lower two categories were eliminated, leaving only the highest two categories available for analysis.

The statistical relevance and p-values discussed in the following sections are as obtained through the chi-square analysis steps noted above; whereas, charts presented in the figures depict distributions of the entire dataset of survey responses. The discussion will be focused on the percentage difference between district manager selections of the highest valued response categories: Very Satisfied, Very Important, and Very Effective.

5.6.2 Product Quality

Findings: The analysis indicated there were statistically significant differences in the Product Quality performance measures of CM at-Risk school projects and Design-Bid-Build projects when comparisons were made in all areas of Product Quality. As presented in Figures 5.24 and 5.25, significantly larger percentages of responses were provided in the Very Satisfied category by CM at-Risk district managers than were by managers of Design-Bid-Build projects for all individual questions regarding Product

Quality with respect to Overall Product Quality, Exterior, Interior, HVAC, Plumbing, Lighting, and Warranty and Callbacks. CM at-Risk managers responded in the Very

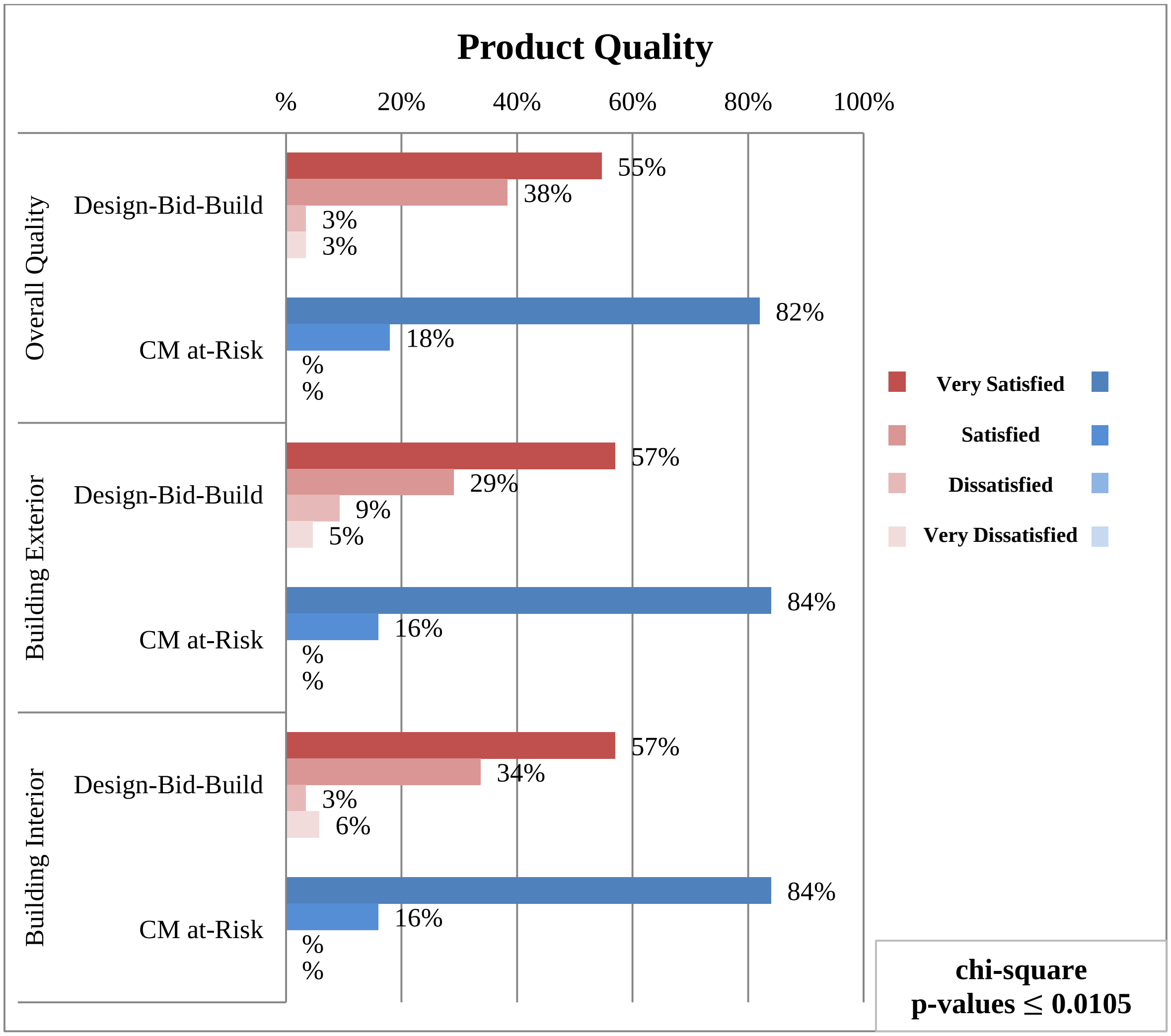


Figure 5.24 Product Quality, Part 1

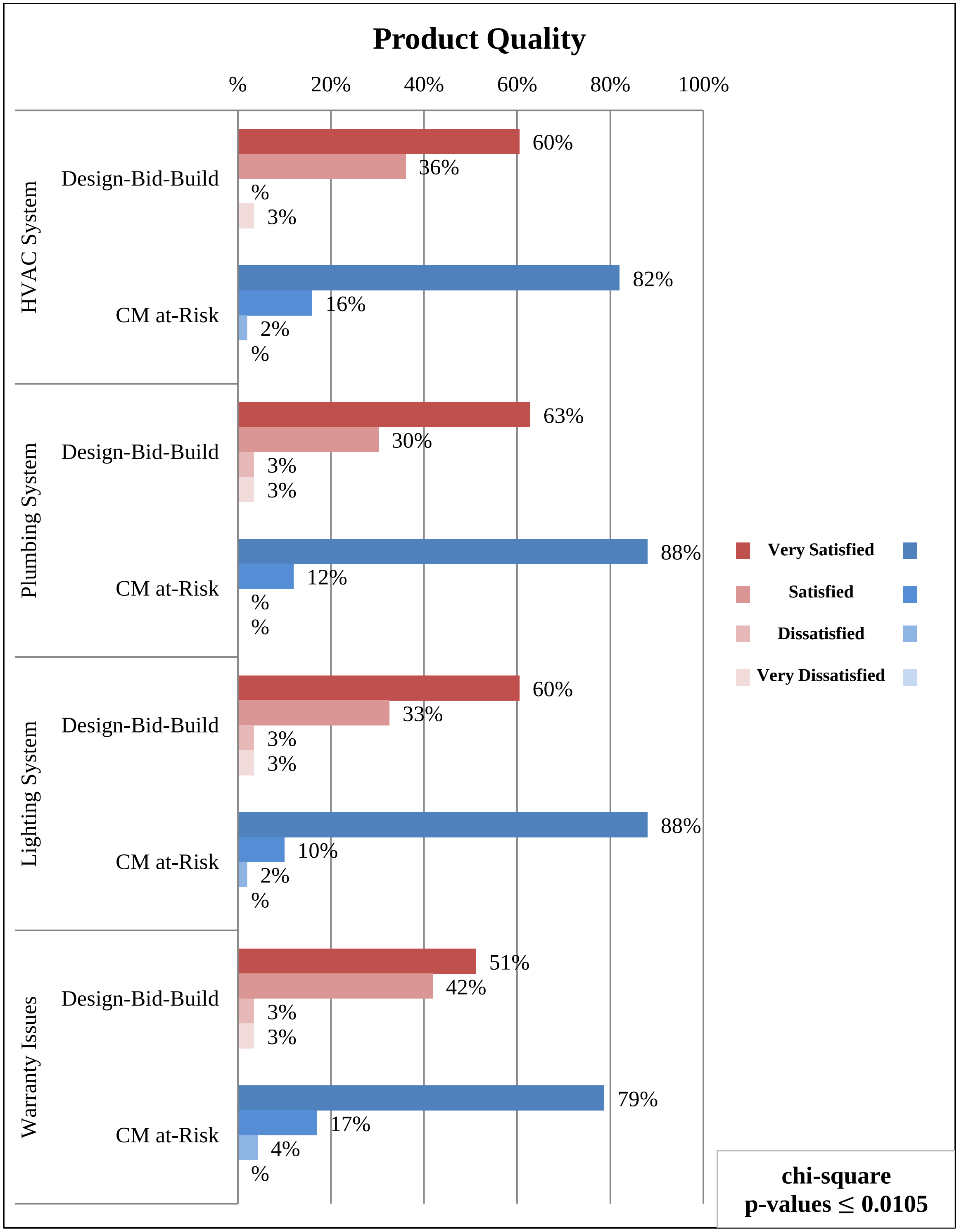


Figure 5.25 Product Quality, Part 2

Satisfied category more than 80% of the time (with the exception of Warranty and Callbacks at 78.7%) with a high of 88% for Lighting Quality. Design-Bid-Build district construction manager responses for Product Quality survey questions in the Very Satisfied category ranged from a high of 62.8% for Plumbing to a low of 51.2% for the Warranty and Callback question. The chi-square analysis of the district manager responses produced statistically significant results indicating that the performance of the CM at-Risk method for construction of public school projects was superior to Design-Bid-Build in all areas of Product Quality with p-values ≤ 0.0105.

5.6.3 Service Quality, Construction Team

Findings: The analysis indicated there were statistically significant differences in the Service Quality performance measures of CM at-Risk school projects and Design-Bid-Build projects when comparisons were made in all areas of Construction Team Service. As shown in Figures 5.26 and 5.27, significantly larger percentages of responses were provided in the Very Satisfied category by CM at-Risk district managers than were by managers of Design-Bid-Build projects for all individual questions regarding Construction Team Service Quality including: Overall Service, Planning, Cost Control, Schedule Control, Quality Control, Communications, and Cooperation. CM at-Risk manager responses in the Very Satisfied category ranged from a high of 82% for Schedule and Quality Control to a low of 76% for Construction Team Communication and Cooperation. Responses from Design-Bid-Build managers regarding Construction

Team Service issues in the Very Satisfied category ranged from a high of 51.2% for Overall Performance to a low of 42.9% for Schedule and Quality Control. The chi-square analysis of the district manager responses produced statistically significant results indicating that the performance of the CM at-Risk method for construction of public school projects was superior to that of Design-Bid-Build in all areas of Construction Team Service Quality with p-values ≤ 0.0083.

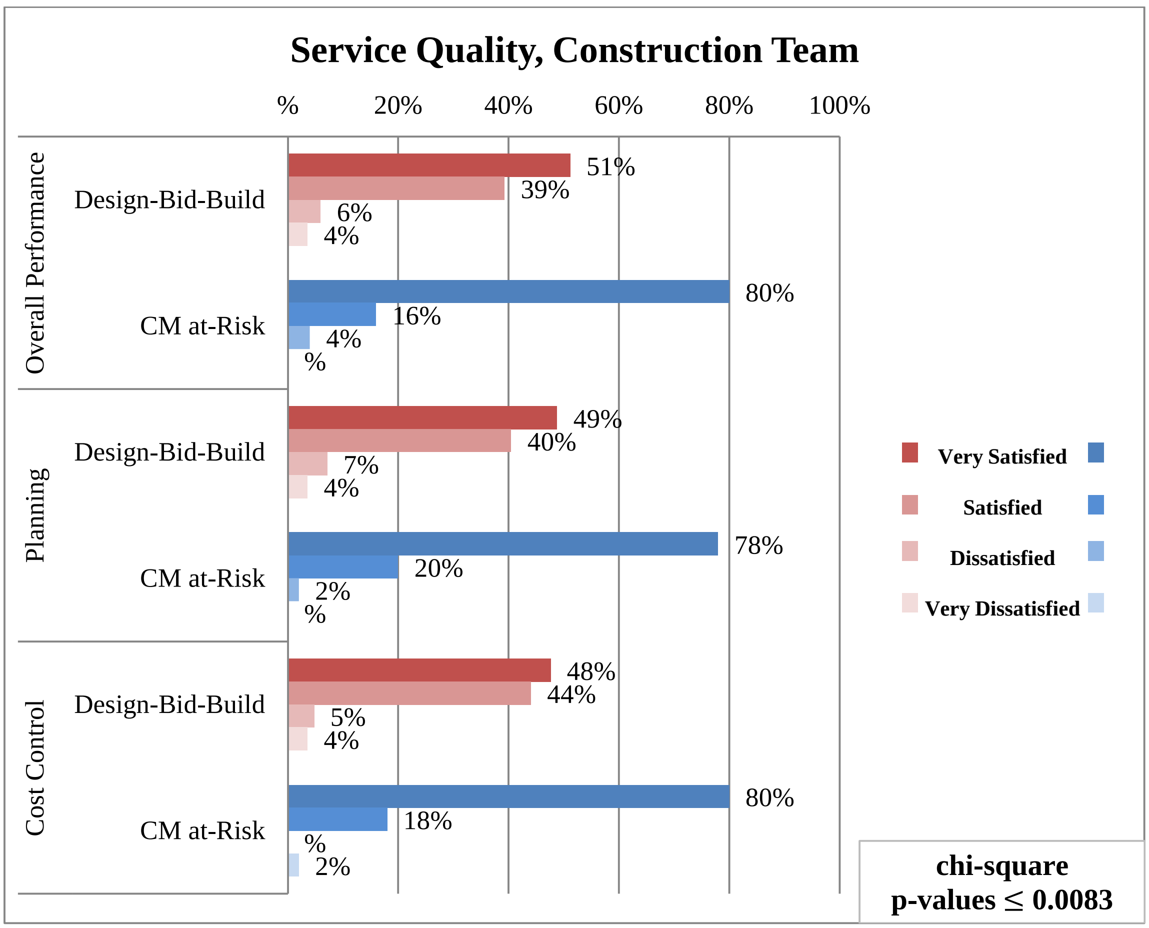


Figure 5.26 Service Quality, Construction Team, Part 1

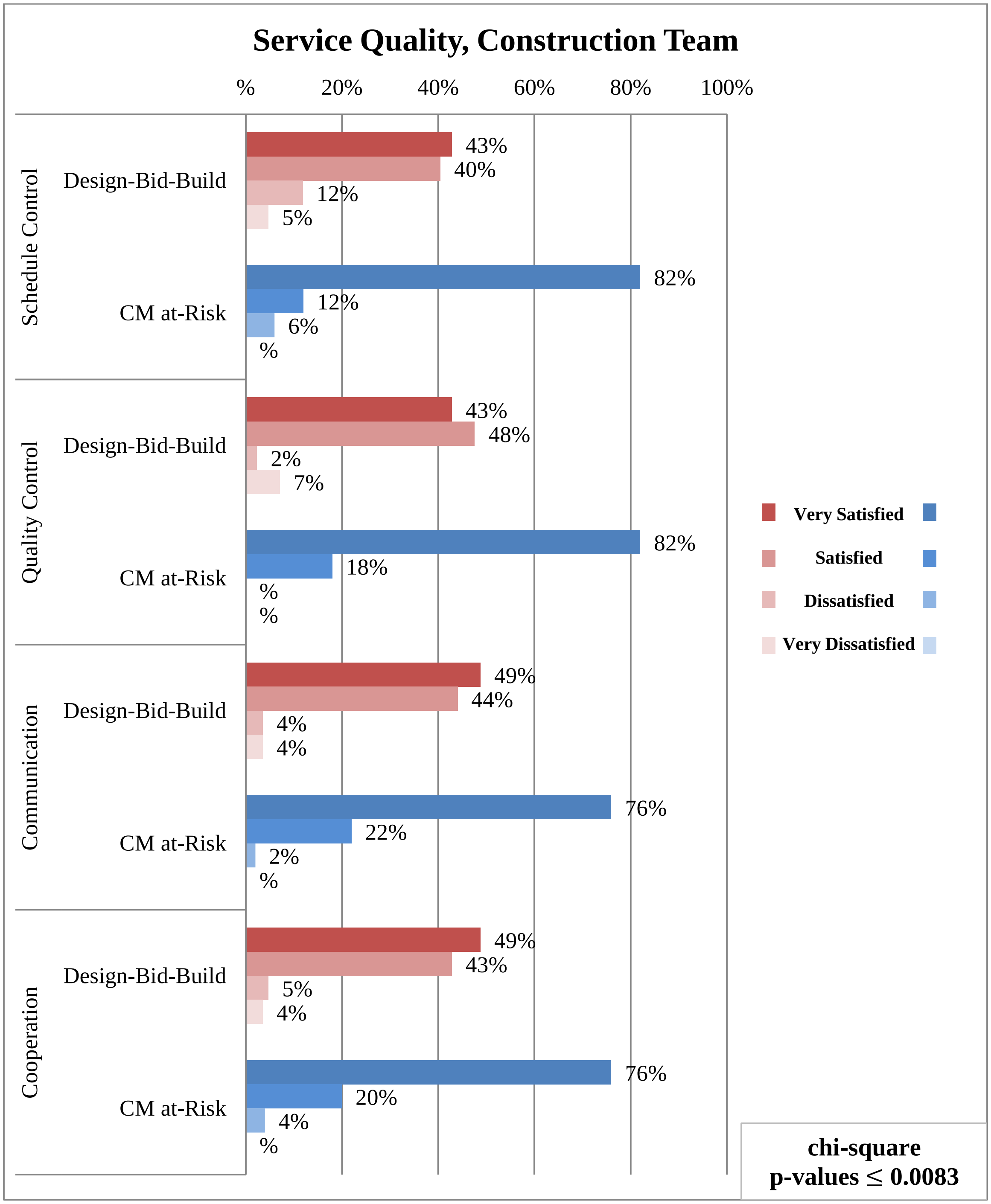


Figure 5.27 Service Quality, Construction Team, Part 2

5.6.4 Service Quality, Design Team

Findings: The analysis indicated there were statistically significant differences in the Service Quality performance measures of CM at-Risk school projects and Design-Bid-Build projects when comparisons were made in all categories* of Design Team Quality. A significantly larger percentage of responses were provided in the Very Satisfied category by CM at-Risk district managers than were by Design-Bid-Build managers for all individual survey questions regarding Design Team Service Quality with respect to Capture Owner Vision, Complete Documents, Communication, Timely Responses, Clearly Defined Documents, and Cooperation. CM at-Risk district manager responses in the Very Satisfied category ranged from a high of 84% for Design Team Cooperation to a low of 68% for Clearly Defined Documents. Design-Bid-Build manager responses in the Very Satisfied category ranged from a high of 56.98% for Capturing Owner Vision and Cooperation to a low of 45.35% for the Design Team Complete Documents.

*As noted in Figure 5.28, Capture Owner Vision and Clearly Defined Documents responses were marginally outside of the significant region with chi-square probability values of 0.0562 and 0.0532 respectively. Additional testing of Clearly Defined Documents by Large and Small categories produced a statistically significant result in favor of Large CM at-Risk projects with 69.44% responses in the Very Satisfied category vs. 43.33% for Design-Bid-Build with a p-value of 0.0463. Testing of Capture Owner Vision did not produce statistically significant results.

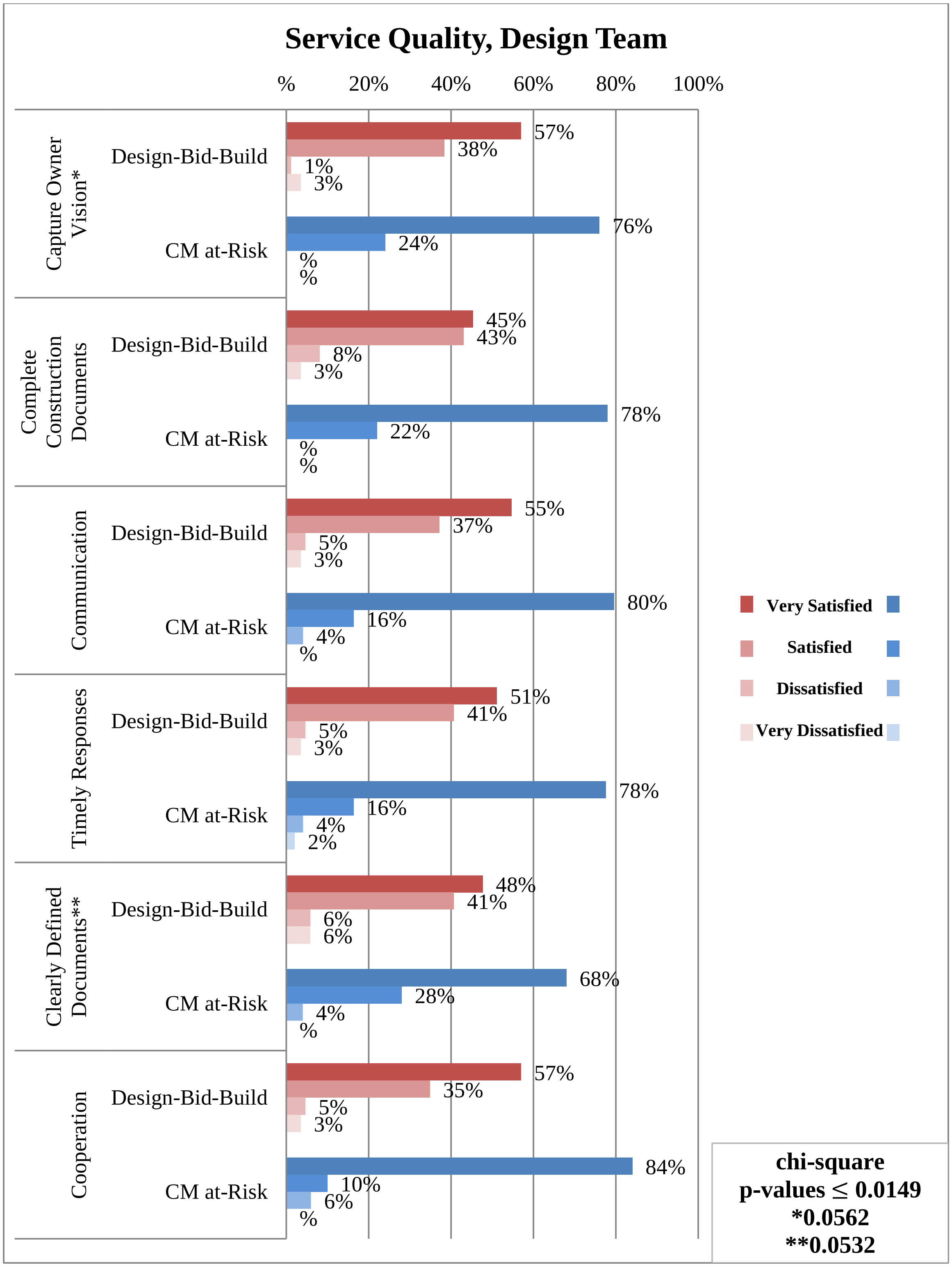


Figure 5.28 Service Quality, Design Team

5.6.5 Service Quality, Project Team

Findings: The analysis indicated there were statistically significant differences in the Service Quality performance measures of CM at-Risk school projects and Design-Bid-Build projects with a p-value of ≤ 0.0039 when comparisons were made in all categories of Project Team Service Quality with the exception of the Communications category with a p-value of 0.0864. As presented in Figure 5.29, a significantly larger percentage of responses were provided in the Very Satisfied category by CM at-Risk district managers than were by Design-Bid-Build managers for all individual survey questions regarding the Project Team Service Overall, Communication, Cooperation, and Collaboration. CM at-Risk responses in the Very Satisfied category ranged from a high of 82% for both Overall and Cooperation to a low of 70% for Project Team Communication. Design-Bid-Build district manager responses for Project Team Service issues in the Very Satisfied category ranged from a high of 53.49% for Project Team Cooperation to a low of 50.0% for Collaboration.

5.6.6 Owner, Contractor, and Architect Experience Levels

Findings: Statistically significant differences were experienced during comparison of owner, contractor, and architect experience levels with a particular type of project delivery method. Managers responded that all parties had more experience on 3 or more projects more often with Design-Bid-Build than with CM at-Risk (owners 94.19% vs. 80.39%, contractors 98.82% vs. 87.76%, and architects with 96.47% vs. 86.96%) with p-values ≤ 0.0092. This was expected due to the fact that the Design-Bid-Build method has been in use for a longer period and is more widely utilized. Manager responses indicated that all participants were well experienced with the use of both methods.

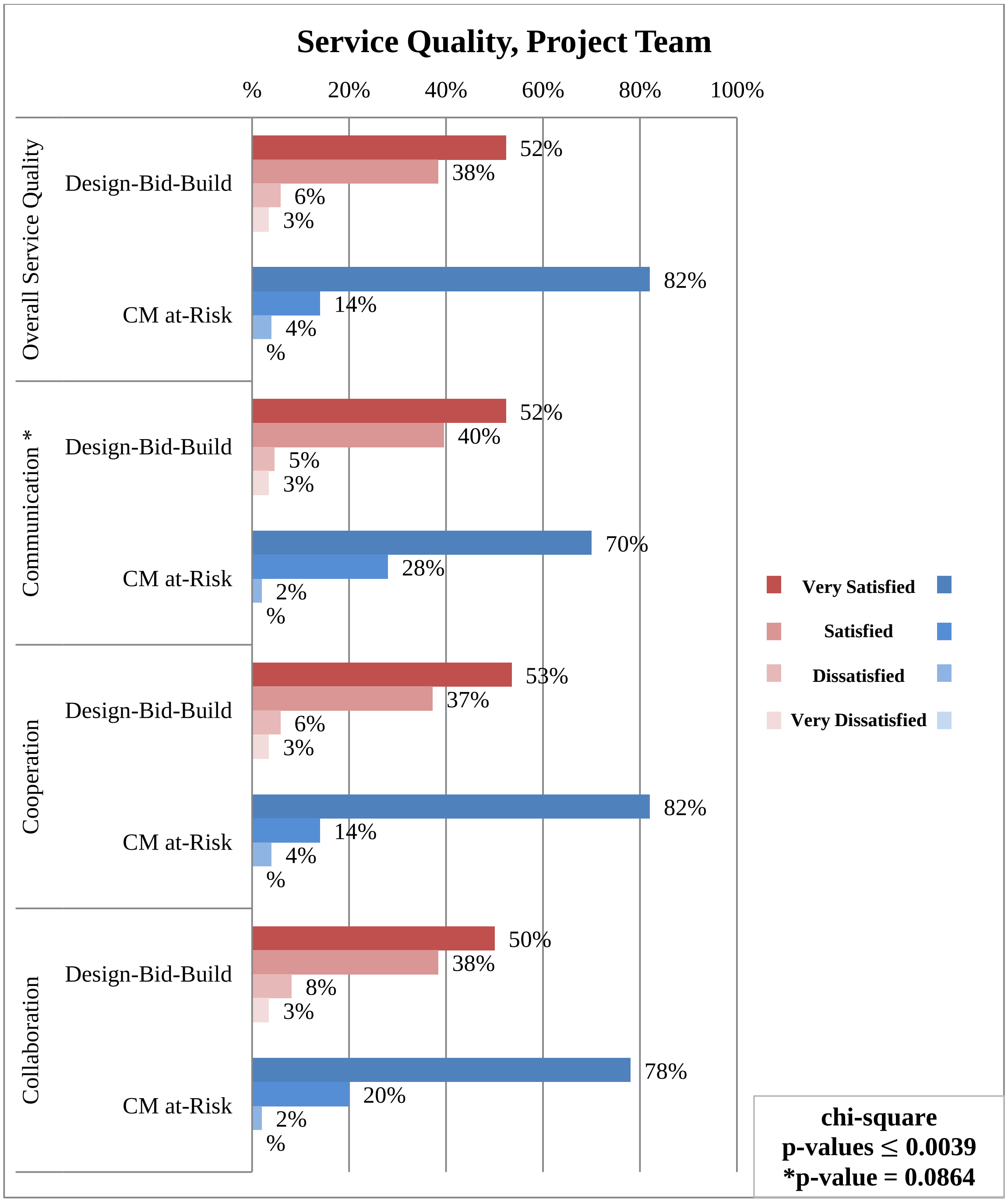


Figure 5.29 Service Quality, Project Team

5.6.7 Selection of Project Delivery Methods

Findings: Statistically significant differences were experienced with responses to the question asking whether the policies of the school district required utilization of a particular project delivery method for the construction of their projects with a p-value of 0.0011. As shown in Figure 5.30, 29.1% of Design-Bid-Build district managers (five times that of CM at-Risk managers at 5.9%) responded that a specific project delivery method was required. As suspected, this confirms that a large number of projects within this study, 20% of all projects, are being completed in districts that require utilization of a particular method. It also shows that those district managers with the greatest degree of flexibility, CM at-Risk managers at 94%, are choosing CM at-Risk. In a related question, managers were asked whether their districts utilized more than one type of delivery method for construction of their projects. For this question, 67% of district managers that utilize CM at-Risk and 72% of those that utilize Design-Bid-Build (70% of all respondents) responded that their districts did not utilize more than one type of delivery method as picture in Figure 5.31.

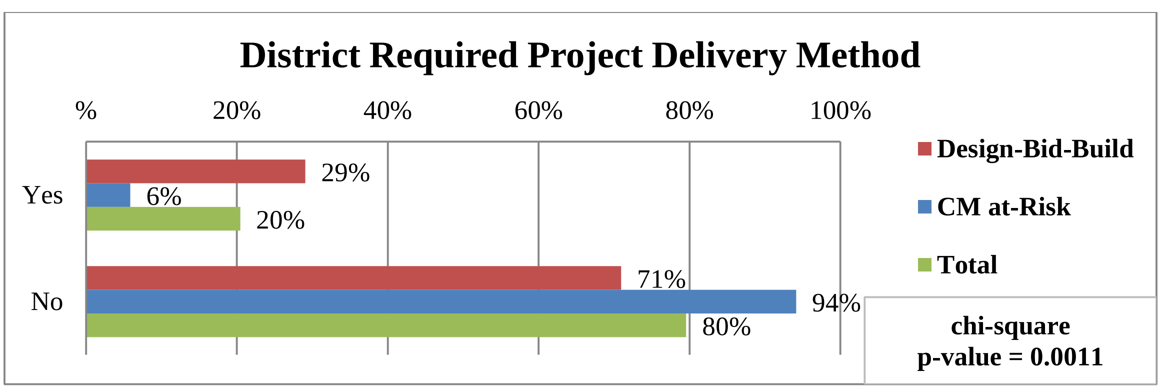


Figure 5.30 District Requirements for Project Delivery Method

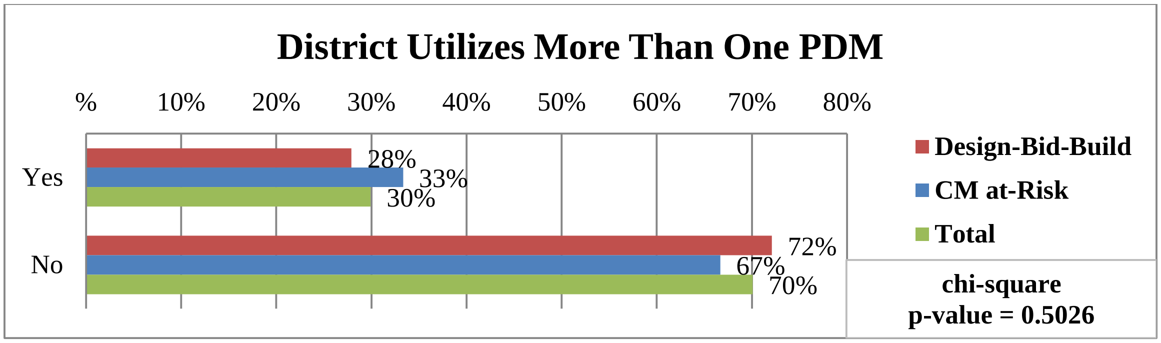


Figure 5.31 Utilization of Multiple Project Delivery Methods

5.6.8 Selection Criteria for Project Delivery Methods

Findings: The analysis indicated there were no statistically significant differences between the criteria considered important for project delivery method selection by district construction managers when comparing CM at-Risk school projects against those constructed utilizing Design-Bid-Build. As shown in Figures 5.32 and 5.33, the top 4 issues involved with selection of a project delivery method receiving the largest percentage of Very Important responses by both CM at-Risk and Design-Bid-Build managers, other than due to its requirement by district policy, in order were: Improve Building Quality, Control Schedule Overruns, Reduce Disputes and Claims, and Control Change Orders. A marginally larger percentage of Design-Bid-Build district managers selected Reducing Project Costs and Schedule Durations and Controlling the Design Process than did CM at-Risk managers. Improving Team Relations was selected by a relatively low percentage of managers utilizing both methods as was the Experience Level of Owner, which, strikingly, received the lowest percentage of selection of Very Important issues by CM at-Risk managers.

It must be noted that 4 of the 6 “additional issues” written in by survey respondents related to “important issues to be considered for delivery method selection” noted that the school “board” was more interested in cost issues whereas, the school “administration” was more interested in quality. A complete list of respondent comments separated by question is provided in Appendix L.

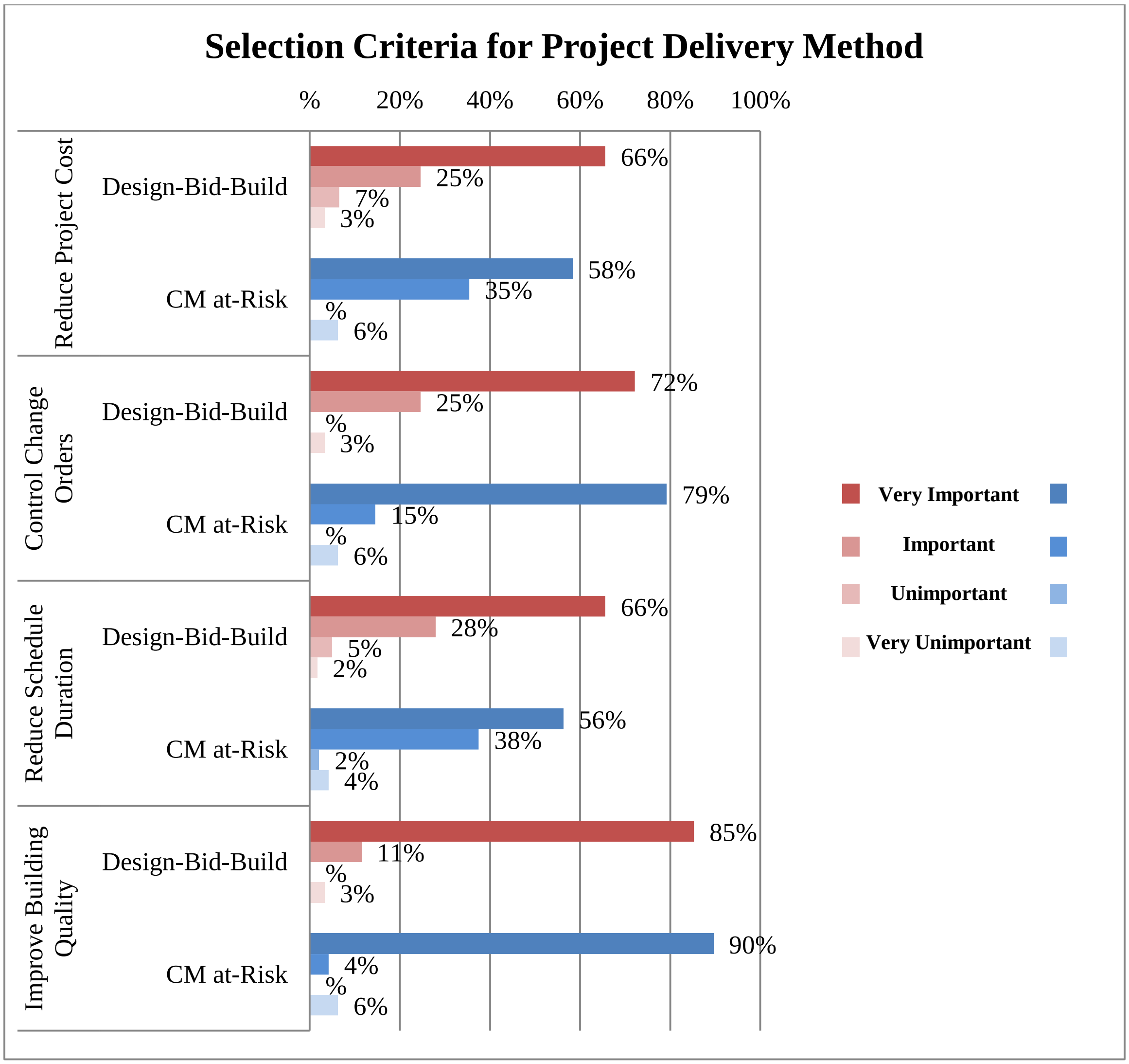


Figure 5.32 Selection Criteria for Project Delivery Methods, Part 1

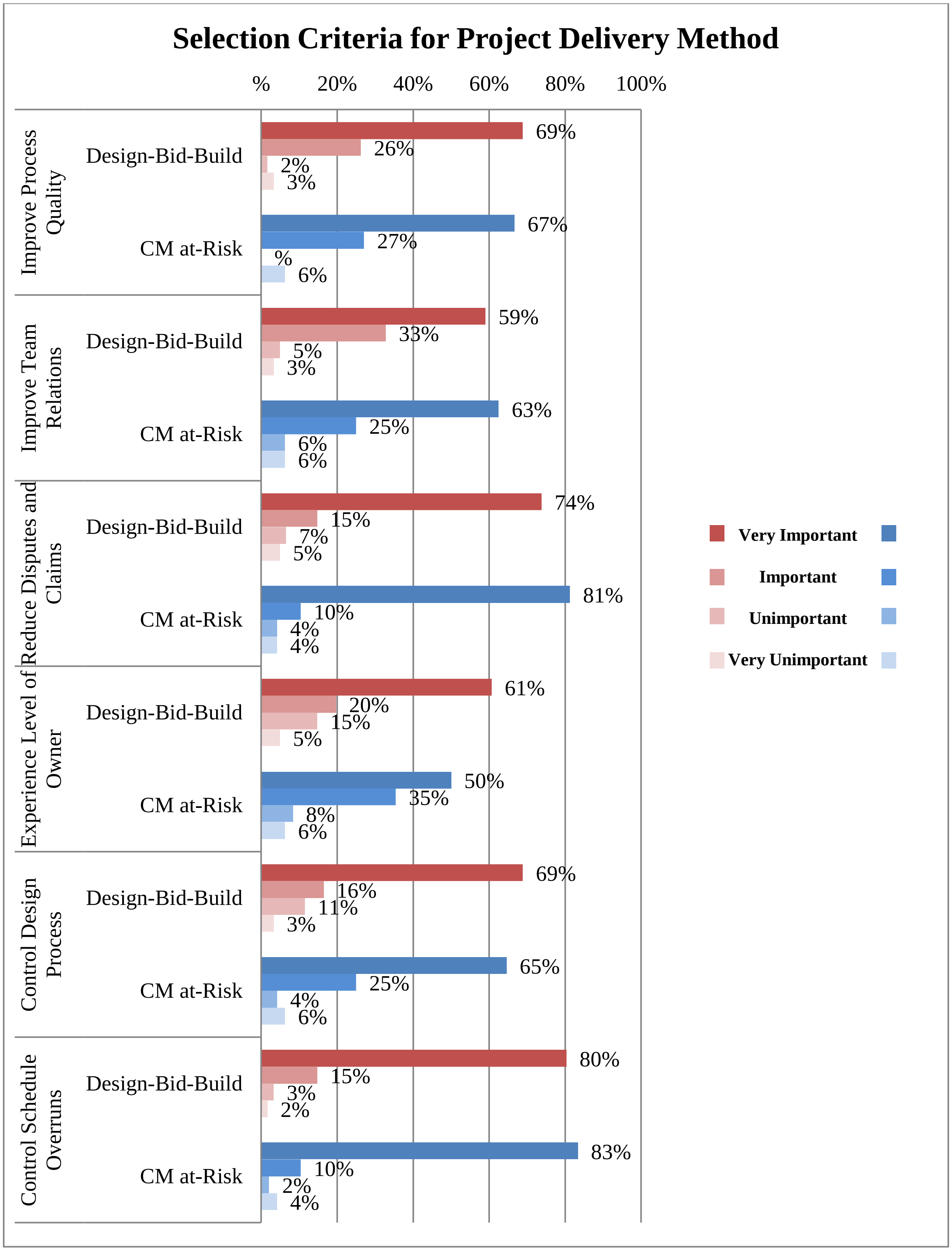


Figure 5.33 Selection Criteria for Project Delivery Methods, Part 2

5.6.9 Effectiveness of Project Delivery Methods

Findings: The analysis indicated there were statistically significant differences in the performance measures of CM at-Risk school projects and Design-Bid-Build projects when comparisons were made in all categories of Delivery Method Effectiveness with the exceptions of Improving Project Team Relations and Controlling the Design Process. A significantly larger percentage of responses were provided in the Very Effective category by CM at-Risk managers than were by Design-Bid-Build managers for all questions regarding: Reducing Cost, Controlling Change Orders, Reducing Schedule Duration, Controlling Schedule Overruns, Improving Building Quality, Improving Process Quality, Improving Project Team Relations, Controlling the Design Process, and Reducing Disputes and Claims.

Although a greater percentage of CM at-Risk managers selected the Very Effective response than did Design-Bid-Build managers, neither group responded as though the method met their expectations as shown in Figures 5.34 and 5.35. The highest percentage of Very Effective responses for both CM at-Risk and Design-Bid-Build owners was for Reducing Disputes and Claims (68.63% CM at-Risk and 41.86% Design-Bid-Build), which seems to show that both groups felt that their method was effective at accomplishing this task. Note that the largest percentages of Very Important responses provided by managers in *selecting* project delivery methods were for Improving Building Quality, which was listed as 6th highest in percentage of Very Effective for both CM at-Risk and Design-Bid-Build (tied for last). Controlling Schedule Overruns was equally selected as the 2nd highest percentage by CM at-Risk managers in both importance for *selection* and effectiveness; whereas, it was selected as the 2nd highest percentage of Very Important for *selection* by Design-Bid-Build and only 6th (tied for last) in Very Effective. Controlling Project Cost was equally selected as the 8th highest percentage (next to last) by CM at-Risk in both Very Important for *selection* and Very Effective.

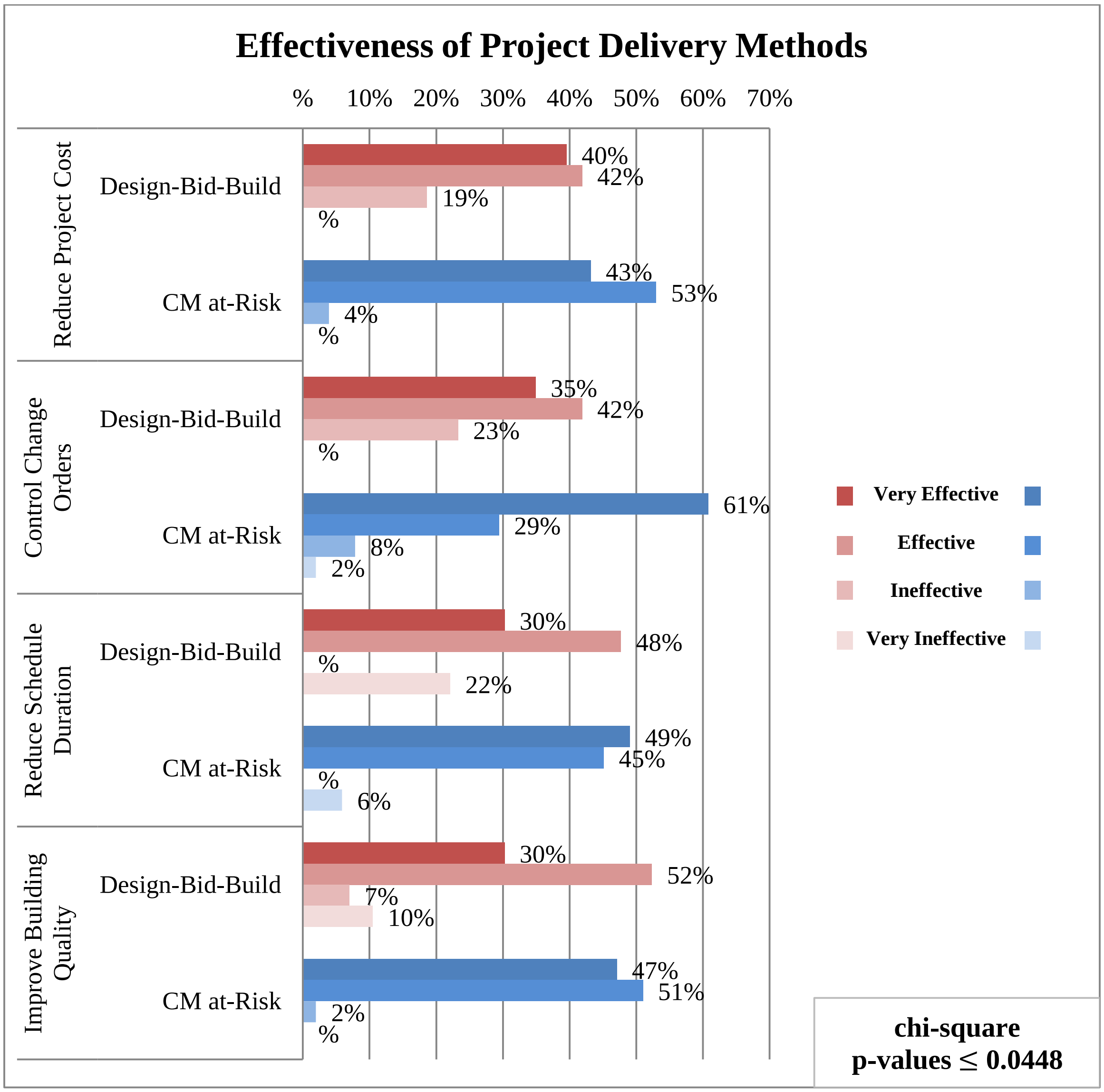


Figure 5.34 Effectiveness of Project Delivery Methods, Part 1

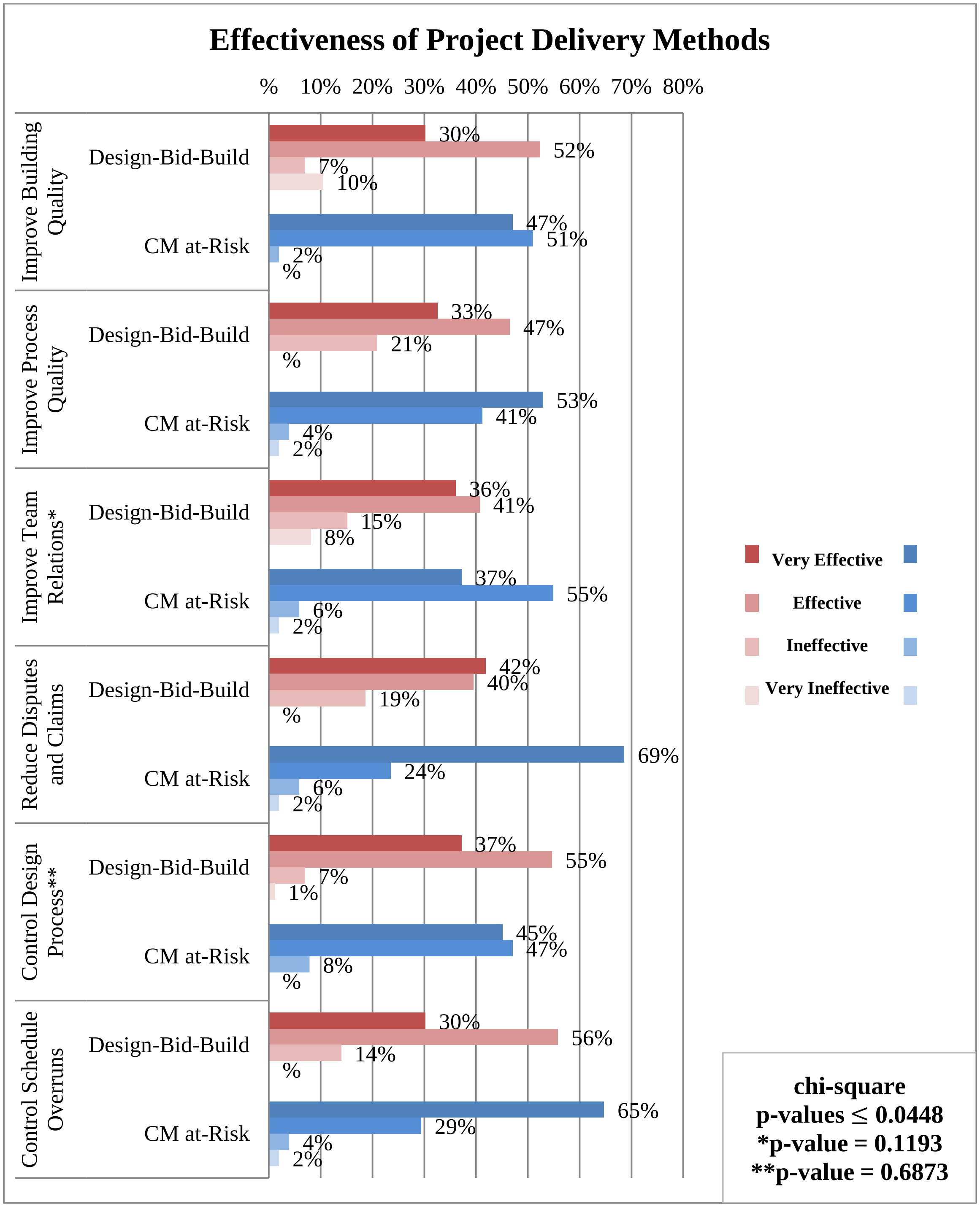


Figure 5.35 Effectiveness of Project Delivery Methods, Part 2

5.6.10 Number and Cost of Disputes and Claims

Findings: The analysis indicated there was not a statistically significant difference in the mean Number of Disputes and Claims between CM at-Risk school projects and Design-Bid-Build projects. CM at-Risk district construction managers reported 5.9%, (3) of their projects with 1-3 disputes and claims whereas, Design-Bid-Build managers reported 9.3%, (8) of their projects within the same range. Because of the relatively small number of disputes and claims reported, there were not enough data to produce a viable analysis regarding the cost difference for this issue. The full range of responses is provided in Figures 5.36 and 5.37.

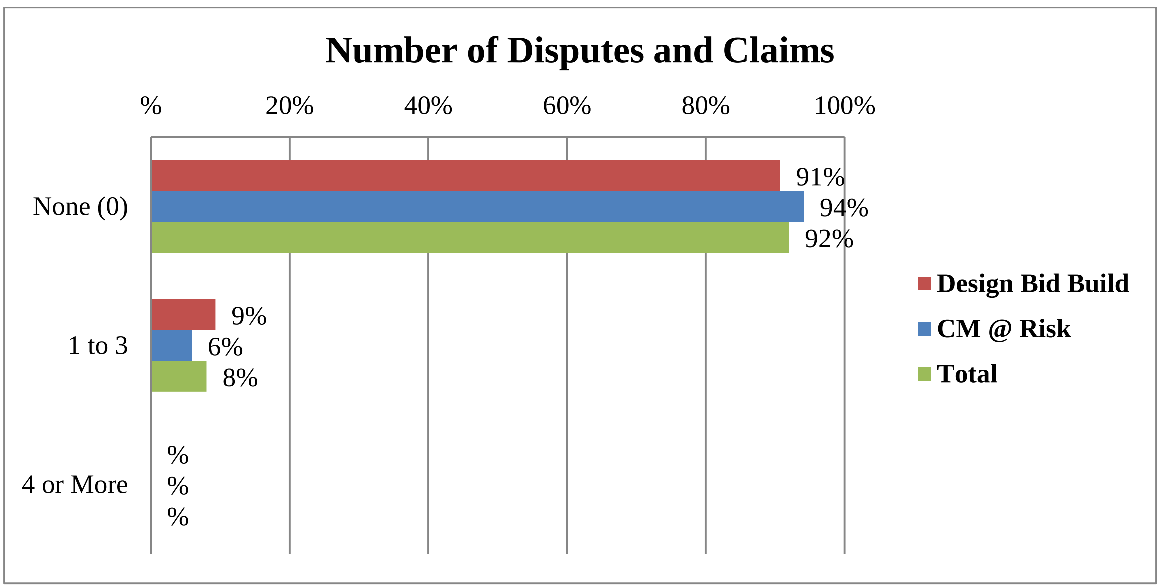


Figure 5.36 Number of Disputes and Claims

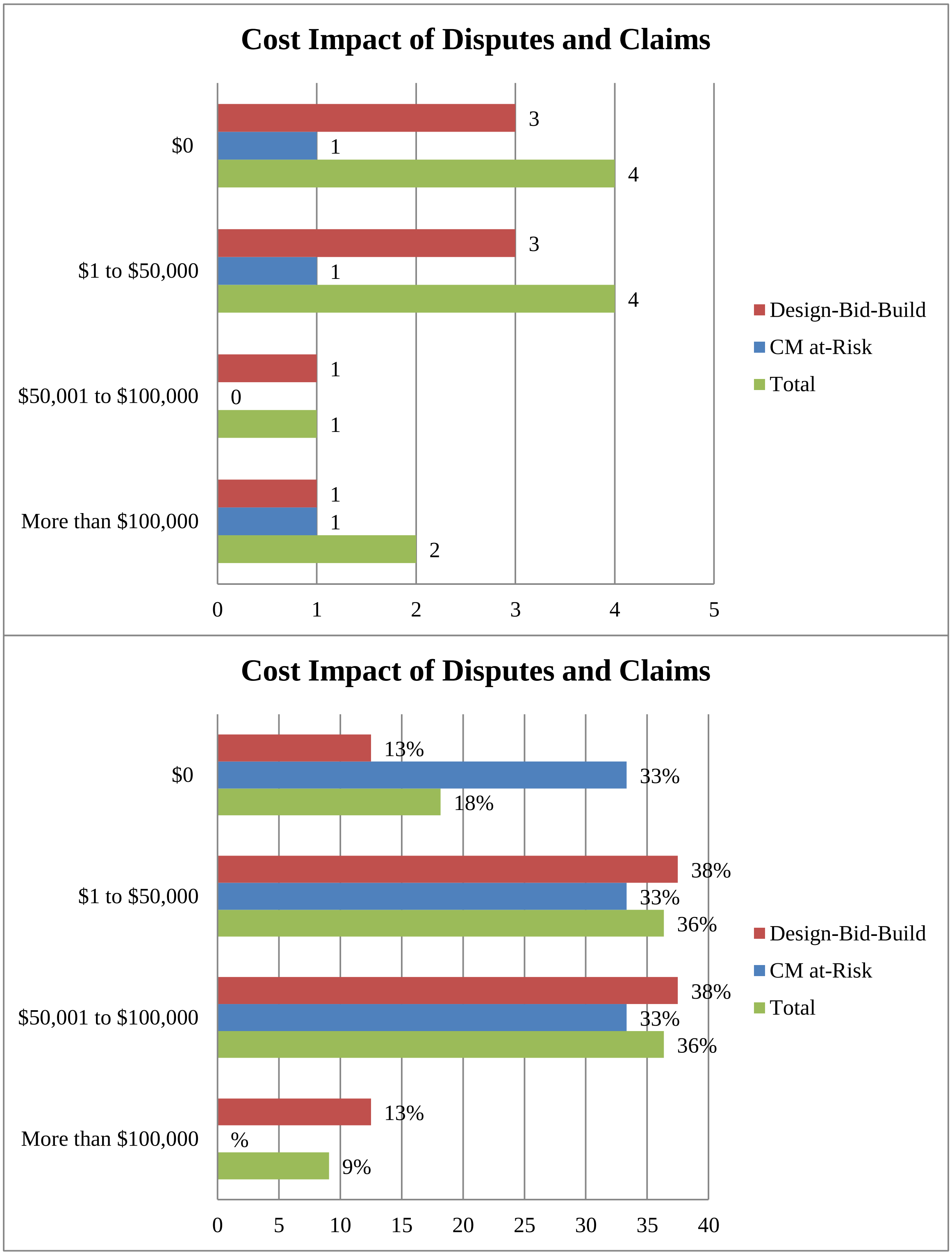


Figure 5.37 Cost Impacts of Disputes and Claims

5.6.11 Number and Cost of Warranty and Callbacks

Findings: The analysis indicated there was not a statistically significant difference in the mean Number of Warranty and Callback issues of CM at-Risk school projects as compared to those constructed utilizing the Design-Bid-Build method. CM at-Risk owners reported 51.2% of their projects with 5 or less issues; whereas, Design-Bid-Build owners reported 61.4% of their projects with the same number. However, the analysis indicated that there was a statistically significant difference in the mean cost of these Warranty and Callback issues. Of the CM at-Risk owners that reported Warranty and Callback issues, 95.12% reported the cost at less than $5,000; whereas, Design-Bid-Build owners reported only 75.72% of their cost issues were less than $5,000. Combined, the evidence indicated that, although the numbers of instances were not significantly different, the performance of the CM at-Risk project delivery method was significantly better at reducing the cost impact of the issues that did occur.

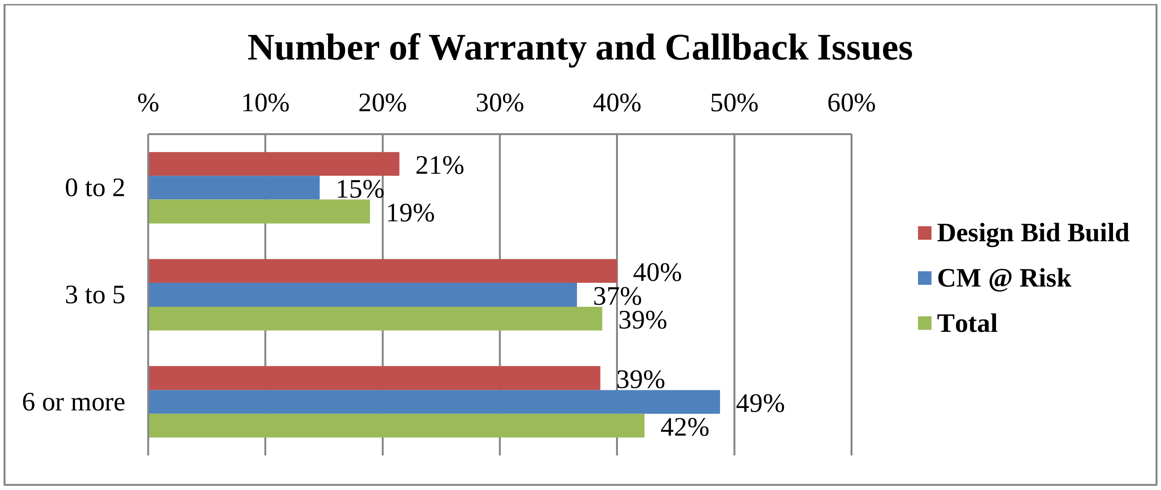
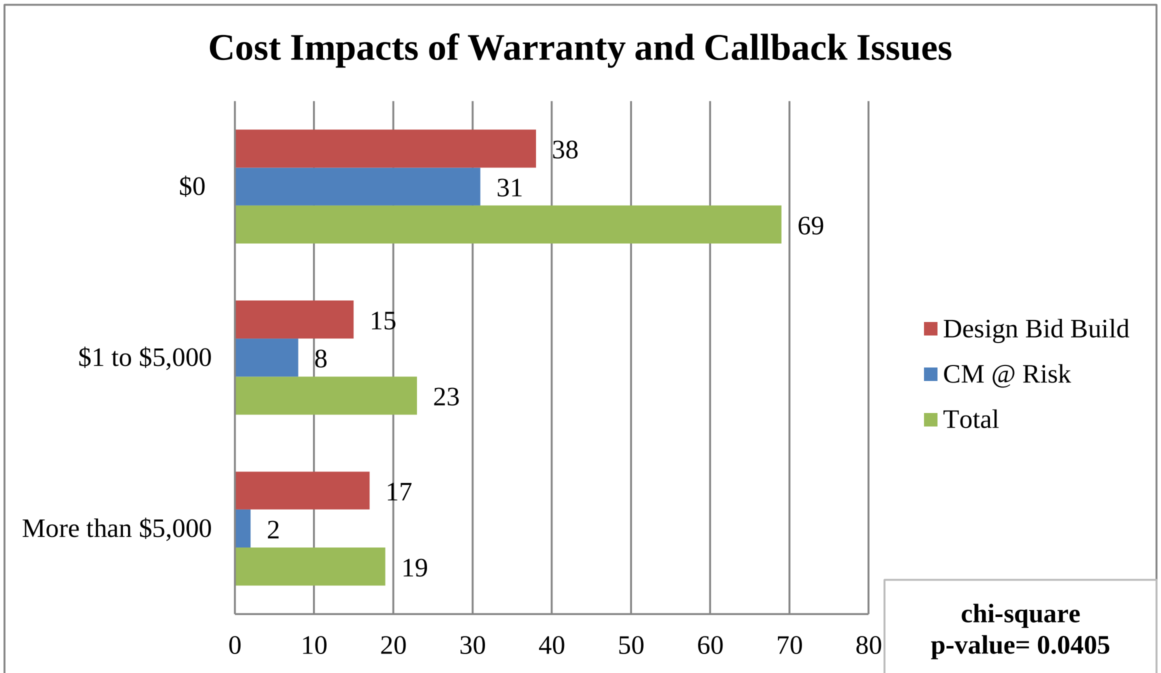


Figure 5.38 Number of Warranty and Callback Issues



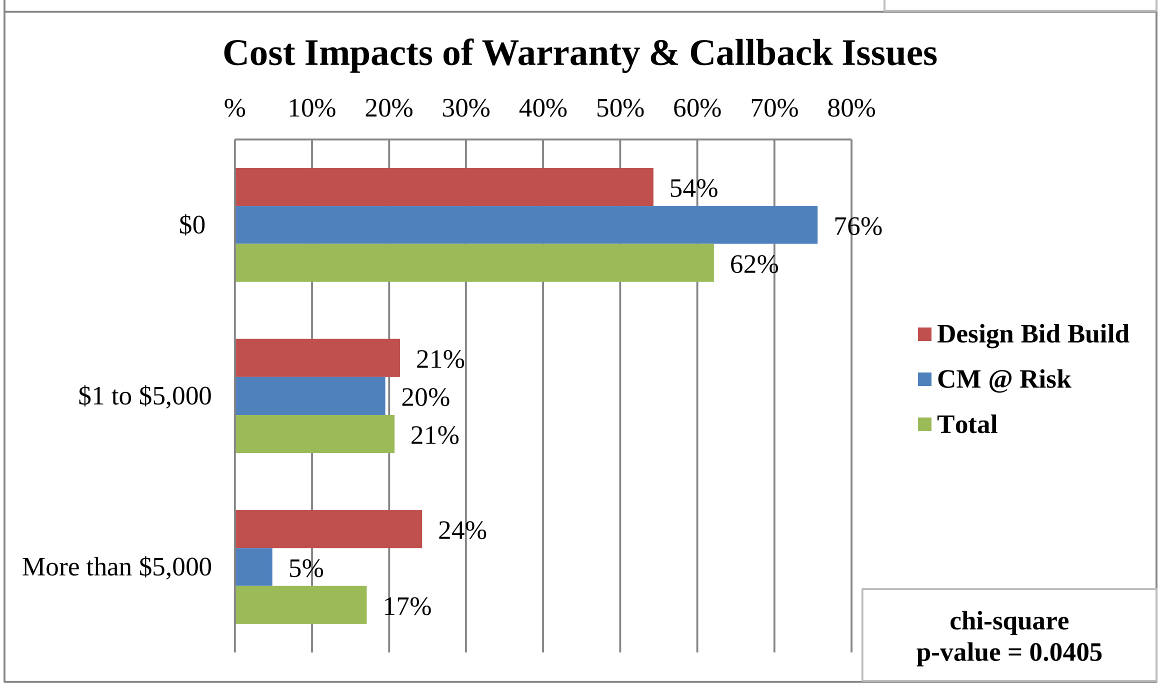


Figure 5.39 Cost Impacts of Warranty and Callback Issues

5.6.12 Procurement Method

Findings: The analysis indicated there was a statistically significant difference in the Methods of Procurement utilized for school projects constructed using the CM at-Risk method and those constructed using the Design-Bid-Build method. Not surprisingly, the vast majority, 74%, of Design-Bid-Build district construction managers procured their school projects utilizing competitive bidding; whereas, CM at-Risk managers predominantly utilized the Qualifications Based Selection (QBS) approach responding at 75%. The chi-square p-value of the analysis was ≤ 0.0001. The follow up question to this issue asked district managers which QBS method was being utilized by their districts. Managers responded overwhelmingly, 82%, that construction fees and total cost were not part of the selection criteria.

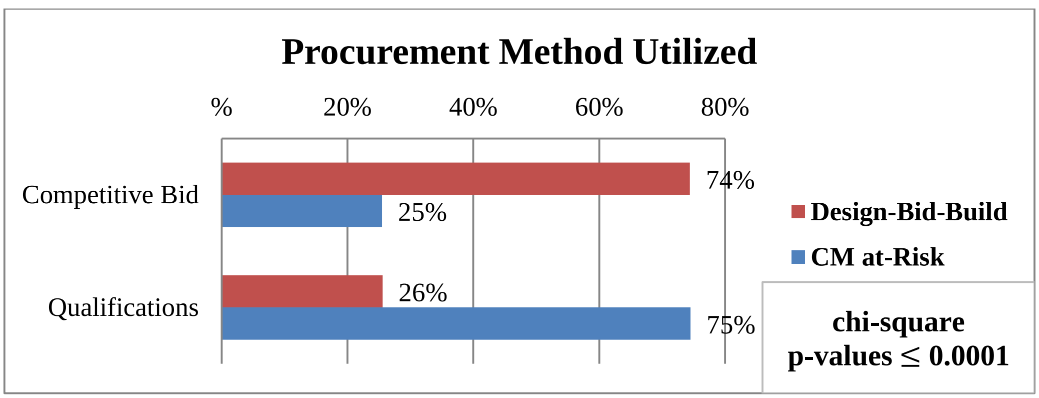


Figure 5.40 Procurement Method Utilized

Note that there is evidence to show that the 26% of Design-Bid-Build managers responding that QBS was utilized for procurement of their projects were most likely only indicating that a prequalification procedure was utilized to screen general contractors prior to the submittal of competitive bids. Prequalification procedures are often utilized for all types of delivery methods to ensure that contractors and designers are both qualified and capable of performing the work they are pursuing (Kenig, 2011). The distinction is that prequalification occurs very early on in the procurement process and refers to who will be considered during the selection procedure; whereas, QBS occurs at the end of the process and is focused on determining how the final selection will be accomplished (Kenig, 2011). The evidence to support that prequalification was being improperly considered by the Design-Bid-Build respondents for this question lies in the 23% response rate provided by Design-Bid-Build district managers that the QBS process utilized had *NOT* included construction fees and total construction costs. By definition, Design-Bid-Build projects cannot be procured without including the total construction cost as part of the selection criteria (Kenig, 2011).

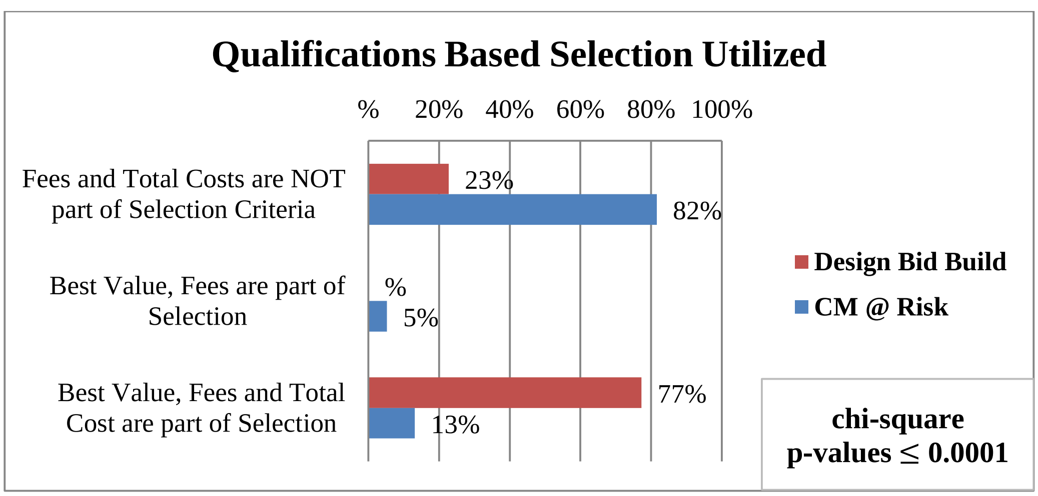


Figure 5.41 Qualifications Based Selection Utilized

This concludes the data analysis chapter. The conclusions and recommendations chapter that follows will open with a review of the impetus behind the study and a reexamination of the research questions. The focus of the final chapter will be on drawing conclusions from the empirical findings based on the theoretical implications, discussing the research significance, and summarizing the completed research.

CHAPTER 6:

CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

The driving force behind this research was to address the ongoing question within the construction industry of which project delivery method, CM at-Risk or Design-Bid-Build performed at a higher level in terms of cost, time, quality, and claims. In so doing, this study was focused on providing current, statistically significant, empirical evidence defining the comparative performance attributes of both methods when utilized for the construction of public schools. The definitive information was necessary in order to assist decision makers at state and municipal levels in making informed choices when selecting the most appropriate project delivery methods for the construction of their public schools. An examination of the characteristics of the construction industry, the development of project delivery methods, and the existing research revealed that a limited body of knowledge existed to answer the following research questions:

1. How do public school projects in Florida, Georgia, North Carolina, and South Carolina constructed using the CM at-Risk project delivery method compare to those constructed using the Design-Bid-Build method utilizing the performance metrics of cost, time, and quality?

2. Is there a statistically significant difference in the number and severity (in terms of cost) of construction claims for public school projects constructed utilizing the CM at-Risk and Design-Bid-Build project delivery methods?

3. What criteria do school district administrators acting in the capacity of public owners utilize to make project delivery method selections?

Therefore, the foregoing research has been conducted. The purpose of this chapter is to present the conclusions and recommendations stemming from the study. The manner in which the empirical findings have resolved the research questions are described in the next section. This will be followed by a discussion of the impact the findings may have on the existing theoretical constructs posited by previous researchers. The chapter will conclude with a review of policy implications that may arise due to the significance of the findings and a section noting recommendations for future research.

6.2 Empirical Findings

This section will be utilized to synthesize the empirical findings in order to answer the research questions noted above. Detailed descriptions of the primary and secondary empirical findings have been provided in Chapter 5. A summary of the empirical findings for the cost and time metrics is provided in Appendix M.

Analysis of school project performance data and survey responses furnished mixed results:

- **Conclusive evidence was provided showing that the performance of the Design-Bid-Build project delivery method was significantly superior to that of the CM at-Risk method for the construction of public schools when comparisons were made across all cost metrics.**

    - The results were a little less convincing when the projects were compared by project type and by state due to the limited numbers of projects within each of the individual categories. However, the evidence clearly indicated that the means for both construction and project costs were higher for the CM at-Risk public school projects.
    - As previously discussed, the cost performance is not necessarily an indication of project value. Projects employing high performance materials, systems, and methods may or may not achieve life cycle cost benefits. Costs associated with these issues were not measured or included within this study.

- **Conclusive results were obtained through analysis of the district construction manager survey responses demonstrating that the CM at-Risk method produced significantly higher levels of product and service quality performance than did the Design-Bid-Build method.**
    - However, since almost all managers were relatively satisfied with the delivery methods selected for the construction of their projects, the results primarily illustrated the degree to which the managers were satisfied.

- **Conclusive evidence does not exist to support the superiority of either of the delivery methods in terms of cost growth, time (schedule duration), time variance (schedule growth), claims, or warranty and callback performance.**

Since neither of the methods considered within this study was superior in all or a large majority of the areas tested, public school decision makers empowered with the authority to make project delivery method selections will be required to make the selection as part of an overall value assessment. Decision makers must determine which criteria are most important for their districts and to what degree prior to making their optimal delivery method selections. Table 6.1 presents the data from this research that can be utilized to assist in this purpose.

Table 6.1 Comparison of Importance and Performance of Project Delivery Method Selection Factors

Comparison of Selection Factor Importance and Performance							
	Survey Responses: Importance in Determining Method Selected		Statistical Analyses: Project Performance and Survey Data				
FACTOR	**CMR**	**DBB**	**CMR**	**DBB**	**NEITHER**	**DIFFERENCE**	**p-value**
Product Quality	1	1	✓	-	-	39.57% [3]	0.0058
Project Schedule Growth %	2	2	-	-	✓	19.69% [7]	0.4760
Disputes & Claims	3	3	-	-	✓	3.77% [5]	0.4764
Project Cost Growth %	4	4	-	-	✓	28.47% [6]	0.5699
Service Quality	5	5	✓	-	-	56.70% [4]	0.0025
Design Process	6	5	✓	-	-	47.42% [9]	0.0036
Project Team Relations	7	10	✓	-	-	56.00% [8]	0.0039
Project Cost	8	7	-	✓	-	22.33% [1]	0.0250
Project Time	9	7	-	-	✓	1.50% [2]	0.8250
Experience Level of Owner	10	9	-	✓	-	14.65% [10]	0.0124
Warranty & Callbacks	Not Asked	Not Asked	-	-	✓	26.47% [11]	0.5104
Project Intensity SF/Day	Not Asked	Not Asked	-	-	✓	3.84%	0.6084
Project Intensity $/Day	Not Asked	Not Asked	✓	-	-	25.56%	0.0033
Readiness	Not Asked	Not Asked	-	-	✓	9.93%	0.4708

TABLE NOTES

DEGREE OF SELECTION CRITERIA		
	Factor selected most often	[1] Final Project Cost
		[2] Actual Project Duration
		[3] Workmanship Overall
		[4] Project Team Service Overall
		[5] Number of Claims (projects with zero)
	Factor selected moderately	[6] Construction Cost Growth % (1.25% - 0.32%)
		[7] Project Schedule Growth % (8.11% - 6.52%)
		[8] Project Team Collaboration
		[9] Design Team Cooperation
		[10] Experience Level of Owner with Delivery Method
	Factor selected least often	[11] Number of Warranty & Callbacks (6 or more)

On the right side of the table, the previously discussed results of the statistical analysis of both project performance and survey response data are presented. On the left, the previously discussed analysis of district manager survey responses is presented, which identifies the important success factors for determining delivery method selection. The analysis of these responses revealed no significant differences between the CM at-Risk and Design-Bid-Build. The responses indicated that product quality, controlling project schedule growth, reducing disputes and claims, controlling project cost growth, and improve service quality (in the same order of priority) were considered to be the most important factors in selecting a delivery method. These responses were not unexpected (with the exception of the missing cost control factor shown at a relatively low level of importance) and express the desire of district construction managers to control the quality, schedule, and cost variability on their school projects. The results show that managers utilizing both the CM at-Risk and Design-Bid-Build methods are making their project delivery selections based on the same foundational issues. And, since a larger proportion of district managers selected product and service quality as Very Important factors as opposed to project cost, it stands to reason that the majority of these managers would be more inclined to select the CM at-Risk method. This reasoning is supported by the previously presented evidence showing that managers with the greatest degree of flexibility selected the CM at-Risk method. Additionally, evidence of user satisfaction with the CM at-Risk selection was provided when the majority of users of that method indicated they did so as their exclusive method of choice. And, although the majority of all projects were completed utilizing Design-Bid-Build, this larger proportion is influenced by the 29% of Design-Bid-Build managers (five times that of CM at-Risk) that are required to utilize that method due to district policy.

The empirical evidence obtained through analysis of the project performance and survey response data as presented above can be utilized to assist public school decision makers to properly link project success factors important to their districts with the methods most appropriate for delivering their projects.

6.3 Theoretical Implications

The literature has exposed many important issues within the construction industry including high levels of risk, project complexity, and a lack of trust among the participants for which the CM at-Risk project delivery method is theoretically equipped to improve, alleviate, or control. These issues will be discussed within this section in conjunction with the supporting and contradictory evidence produced by this research and will include possible explanations for theoretical differences.

6.3.1 Collaborative Properties and Benefits

It has been shown that the construction industry is fraught with risk, which is often due to the increasingly complex, fragmented, and dynamic industry (Saporita, 2006; Zaghloul & Hartman, 2003; Akintoye & MacLeod, 1997; Gordon, 1994; Kangari, 1995; Al-Bahar, 1990). Additionally, Vincent and McKoy (2008) have stated that "public school construction is immensely complex," stemming from the volume of issues related to statutory and regulatory requirements, planning and design, timing and scheduling, diversity of the parties involved, and budgetary considerations. The work of Forester (1989) focused on complex relationships, communication, and power issues associated with fragmentation and, since project teams are composed of diverse parties with interdependent interests, construction issues can have similarities with Rittel and Webber's (1973) wicked problems. On construction projects, these issues lead to poor communication, the perception of risk, and lack of trust among the parties directly correlating with higher risk premiums in the form of increased costs and project durations (Zaghloul & Hartman, 2003). The research of Innes and Booher (2010) has shown that traditional methods of problem solving may not be adequate for dealing with complex and dynamic issues, such as those encountered in the construction industry, suggesting instead that collaborative methods would be more beneficial. Proponents of alternative delivery methods believe that utilization of these methods fosters a collaborative work environment among the owner, architect, and contractor project team members, providing the opportunity for improved performance in terms of productivity, cost, time, and project quality (NRC, 2009; O'Connor, 2009; Sanvido & Konchar, 1999; Kenig, 2011; AIA/HOK, 2004; Paulson, 1976). The CM at-Risk method of project delivery is considered to be more collaborative in nature than is the Design-Bid-Build method (Konchar, 1997; Kenig, 2011). Additionally, selection of the CM at-Risk early on in the process utilizing a Qualifications Based procurement method is expected to improve the collaboration between parties by increasing trust and improving communication (Kenig, 2011; AIA/HOK, 2004; Paulson, 1976). Furthermore, the collective development of the GMP by the entire project team combined with open-book reviews of cost and change order issues is said to improve the risk environment leading to higher quality and reduced costs (Kenig, 2011). Note however that the research of Sanvido and Konchar (1999) provided results showing that the unit costs of CM at-Risk projects were only marginally lower, 1.6%, than were those completed utilizing the Design-Bid-Build method.

Evidence has been provided by this research showing that the collaborative properties of CM at-Risk performed at significantly higher levels than did those of Design-Bid-Build. District construction manager responses to survey questions specifically focused at the collaboration and cooperation of the construction team, design team, and project team produced significant positive results in favor of CM at-Risk. Additionally, product and service quality were shown to be superior for CM at-Risk with significant differences in all areas except for design team capture of owner vision and providing clearly defined documents. However, one indication that collaboration on CM at-Risk projects only marginally exceeded that of Design-Bid-Build was seen during the examination of the question regarding the effectiveness of the project delivery method at improving the relationships of the project team. This was one of only two responses (controlling the design process being the other) related to delivery method effectiveness that did not achieve a significantly higher rating from managers of CM at-Risk projects. Still, the preponderance of evidence provided by the district manager responses supports the work of Konchar (1997) and Konchar and Sanvido (1998) and the theoretical construct that collaborative environments positively influence the performance of product and service quality on public school construction projects.

Conversely, in support of the Williams (2003) research, the collaborative properties of the CM at-Risk method were not able to produce significant performance enhancements in the areas of cost, time, and risk. Testing of all construction and project cost metrics produced results showing that CM at-Risk cost performance was significantly inferior to that of Design-Bid-Build. Additionally, examination of all time, project intensity SF/Day, and risk metrics revealed no significant differences between the two methods.

The initial explanation for a portion of the differences experienced between this study and that of the foundational research could be due to the fact that the current research was focused on public sector projects that were similar in both size and type. Alternatively, as originally exposed as a weakness by Williams (2003), the foundational research efforts completed by Konchar (1997) and Konchar and Sanvido (1998) were completed utilizing data from a wide variety of project types including multi-story residential, simple and complex office, light and heavy industrial, and high-tech. Furthermore, the projects included in these studies were from both the private and public sectors with size categories ranging from 0-50,000 square feet to more than 350,000 square feet.

Another possible explanation for a portion of unrealized cost performance improvements could be attributable to utilization of high performance designs, equipment, and materials for the construction of environmentally sustainable or LEED certified new facilities. As previously noted, high performance materials in conjunction with these processes may cost more in terms of initial construction cost, but district managers expect that these expenditures will allow their facilities to operate more efficiently in terms of cost, environmental, or other issues and thus, provide a better value in terms of life cycle costs. The data collected for this study did not allow for analysis of life cycle costs or the perceived value obtained by their utilization.

Further explanation could be obtained by exploring the specific differences of the two delivery methods in relation to school project complexity. The Design-Bid-Build method is best suited for clearly defined projects, having well designed and complete documents, with relatively low propensities for change, and that do not have greater than average schedule challenges (Gordon, 1994). The method provides for the lowest initial cost due to competitive bidding of the completed documents and a lump sum/fixed cost reimbursement contract. Alternatively, CM at-Risk is best suited for projects in which the final design and construction documents are still uncertain, where changes may be likely to occur during the process, and where schedule reduction may be a significant factor in project success (Kenig, 2011). This method may have higher initial costs due to preconstruction fees and services, but the improved predictability of CM at-Risk is purported to reduce overall costs by limiting change orders, risk, and construction claims (Kenig, 2011). Additionally, early selection of the CM at-Risk during the design process is expected to increase collaboration and enable benefits such as constructability reviews, budget and schedule analyses, and schedule fast-tracking. Public school construction projects have been reported to be complex in nature (Vincent & McKoy, 2008), which seemingly makes these projects a good fit for the CM at-Risk method.

Conversely, evidence has been observed showing that some districts have implemented the use of standardized design features, uniform materials and equipment, and regimented prequalification procedures in efforts to reduce unpredictable construction results. Additionally, although a specific question was not included in the survey instrument to capture these data, a limited amount of write-in evidence was obtained showing utilization of prototype schools and multiple project awards in efforts to capitalize on economies of scale. Furthermore, project data were collected in which it appeared that the CM at-Risk contractors had not been hired early in the process, preconstruction services had not been rendered, and compensation for these services had not been provided. Furthermore, evidence has been presented showing that CM at-Risk district managers rate cost and schedule reduction as relatively low factors of importance when selecting a project delivery method for public school projects, while at the same time, many of them have continued to utilize the CM at-Risk method. Perhaps this is due to their appreciation of the collaborative properties offered by CM at-Risk or, perhaps it is due to district policy requirements. However, the salient point is that the practices of these districts may have reduced the overall complexity of their school construction projects such that the values of the innovative, collaborative, and time saving characteristics of the CM at-Risk method were reduced, and thus, making their projects more suitable for construction utilizing Design-Bid-Build. This could explain why the service or product quality ratings for these projects remain high, while the time, cost, and schedule benefits may not have been manifested.

An additional explanation for a portion of the cost differences could be related to the manner in which contingency allowances are managed. Whereas, owner project contingency allowances are often included within both CM at-Risk and Design-Bid-Build projects, CM at-Risk projects often include additional contingency allowances for undefined design issues and unforeseen conditions related to the construction phase (Kenig, 2011). And, while it is true that prudent district managers of Design-Bid-Build projects would also budget for these same issues, the contingency allowances would typically be held in separate, district-managed accounts and therefore, would *not* be included within the lump sum cost of Design-Bid-Build contracts. These contingency differences could possibly be seen with a comparison of the original construction costs of both methods. However, although testing conducted during this study revealed that the mean original cost of CM at-Risk projects was significantly higher, the cause of the difference could not be determined with the available data. Furthermore, the 24.0% difference noted in the original construction costs was very close to the difference obtained during comparison of the mean final construction costs at 22.7%. And, although there is not conclusive evidence to support the following assertion, the similarities in overages may be due in part to the fact that contingency differences are not always rectified or recognized. For example, even though CM at-Risk contingency allowance expenditures for design and construction issues may have been minimal, anecdotal evidence suggests that unutilized contingency amounts are not always fully transferred back to the district in the form of change orders and thus, are not always technically realized. Sometimes, when district managers (and owners on other types of projects) are notified that cost savings will occur, the managers will utilize these funds to expand the project scope by completing end-user "wish lists," upgrading equipment, or constructing other district projects that have been waiting for funding or approval. The result is that the project scope and thus, the project *value* are increased while the expected savings are unaccounted for due to the lack of reductions in the final construction and project cost accounts. The result is that the *overall project value* has increased, and the construction and project costs appear to have been higher than what actually occurred. It must be noted that this issue is not exclusive to CM at-Risk projects. It should also be mentioned that other possible reasons exist to explain the contingency issues including the simple explanation that the proper and complete construction of these schools may have required utilization of all allocated funding.

In regard to the unrealized schedule performance benefits experienced with CM at-Risk projects, indirect evidence shows that collaborative properties may have positively influenced the durational differences seen between school projects constructed with each method. As previously presented in Figure 5.20, contractors on CM at-Risk projects were awarded 7.7 days more time for change order issues than were Design-Bid-Build contractors. The additional time allowances may have been due to the superior level of collaboration experienced between CM at-Risk project team members. Early involvement and open communication may have led to collective development of original schedules and a more informed team, which could have led to a better understanding of change order issues. The improved knowledge of the facts combined with feelings of shared responsibilities could have enabled the architect and district manager to support more frequent contractor requests or requests for longer periods of time. Additional possibilities may exist to explain the difference in change order schedule allowances including individual or project team sophistication, training, or policies and procedures.

6.3.2 District Manager Experience Requirement

Another theoretical aspect of CM at-Risk utilization requiring discussion is the necessity that district managers and other decision makers involved with the project delivery method selection possess a high level of experience. Client experience tops the list of the human related factors required for construction project success in the research of Chan, Scott, and Chan (2004). Sanvido and Konchar (1999) note that project delivery method selections are based on the personal experience and purchasing philosophy of the decision maker. Additional research by Chan and Chan (2004) explains that the experience and perception of the owner influences the actual definition of project success, which, in turn, influences the project delivery method selection. Bender (2004) writes that the best construction project results may be obtained by pairing the level of owner sophistication with the appropriate (method). As a direct example, Kenig (2011) notes that the reimbursement procedures utilized within the GMP contract for CM at-Risk projects can be difficult to manage for inexperienced owners. These issues combine to show that district manager experience levels should be an issue of primary importance when making project delivery method selections.

And yet, district managers did not indicate that owner experience was an issue of high importance when responding to the research survey. Only 50% of CM at-Risk respondents noted that owner experience level was a Very Important issue, which was the lowest percentage among all delivery method selection factors. Design-Bid-Build managers responded in the Very Important category only 60% of the time for this question, second lowest among their selection factors. Although evidence is not available to draw a definitive conclusion, perhaps the low response rate simply indicates that other issues, such as product and service quality or district policies that mandate utilization of a particular method, are of such high importance that the experience level of the manager is of relatively low importance. However, although almost all respondents indicated that they had high levels of experience with public school projects and their particular project delivery methods, their responses to the owner experience question seem to indicate that district managers do not believe that the CM at-Risk method differs remarkably in procedural complexity from that of Design-Bid-Build and therefore, high levels of owner experience or sophistication are not required to manage school projects when utilizing CM at-Risk. These responses would not be unexpected from those managers exclusively utilizing Design-Bid-Build, since they may indicate a genuine lack of awareness of the differential nature of the CM at-Risk method. And, since Design-Bid-Build is the most widely utilized and easily understood method, one can understand that the managers utilizing that method would possibly not consider it to be markedly complicated. Therefore, manager experience utilizing Design-Bid-Build would appear to be of less importance to these respondents. Both of these explanations seem plausible enough to justify the low level of Very Important responses received from Design-Bid-Build managers. Conversely, it would seem that those managers with a large measure of experience utilizing the CM at-Risk method would believe that issues, such as "risk-sharing" and reduced control, contractor selection based on qualifications rather than price, contractor selection prior to the completion of construction documents, and continuous budgetary and contingency management would inspire a different level of response. Perhaps those utilizing CM at-Risk are so well practiced with that method that the operational aspects of it have become routine and therefore, district managers have become unmindful of the CM at-Risk method's idiosyncrasies such that experience does not seem of high importance. This explanation is compatible with that of the Konchar and Sanvido (1998) clarification regarding owner ratings of project complexity in comparison to their experience levels with particular types of construction.

Additional possibilities for explaining the unrealized cost, schedule, productivity, and risk performance improvements could be related to many issues, including: loss of district manager control of the process, lack of project team sophistication and ability, unrealistic expectations of the method's abilities, or the influences of power combined with a possible disconnect between district policy and the public interest. However, the evidence and analysis required for conclusive explanations to these issues is beyond the scope of this research.

6.4 Policy Implications

From the outset, this research has been focused on providing empirical evidence to assist decision makers at the state and district level in making more informed construction project delivery method selections for their public schools. The results obtained through statistical analysis of the survey and project data have provided conclusive empirical evidence of significant differences in the performance of CM at-Risk school projects in comparison to projects constructed with the Design-Bid-Build method:

- **Public schools constructed with the Design-Bid-Build method cost significantly less than those constructed with the CM at-Risk method.**
- **Public schools constructed with the CM at-Risk method receive significantly higher district manager ratings for product and service quality.**

It is expected that the information provided by this research will enable those in decision-making capacities to make more informed decisions regarding the construction of public schools.

However, this research has also presented results that confirm the previously described anecdotal evidence that district policies and other utilization practices are restricting the ability of managers and other decision makers to select the most appropriate delivery method for construction of their school projects:

- **20% of district managers responded that district policies require a particular method.**
- **70% of district managers responded that their districts only utilize one delivery method**.

Therefore, policy makers within these districts should carefully reexamine their delivery method selection policies utilizing the empirical evidence provided by this research to ensure that their delivery method selections are properly aligned with their district project success factors. For example, those mandating a particular method in order to exclusively focus on achieving lower construction costs should mandate utilization of the Design-Bid-Build method. Conversely, those districts concentrating more on obtaining projects of a higher product quality utilizing a more collaborative process to obtain better service should require utilization of the CM at-Risk method.

However, this research has shown that varying issues inherent in the construction industry and other issues specifically related to public schools may serve to complicate the school construction process to such an extent that those having the responsibility for constructing public schools should also possess the ability and authority to select the most appropriate delivery methods based on the situational aspects encountered. Therefore, in order for the public, school administrators, and district construction managers to benefit most from the information provided by this research, state and district policies should be aligned so that the most appropriate delivery methods may be utilized when those situations requiring them arise. Consequently, it is recommended that state and district statutes, regulations, and policies be modified to allow for the widest possible selection of delivery methods for the construction of public school projects. Additionally, it is recommended that training programs should be developed and administered in order to educate district managers and other decision makers on the benefits and limitations of all project delivery methods, their proper situational utilization, and the levels of district construction manager experience and sophistication required for their successful implementation and utilization.

6.5 Recommendations for Future Research

In order to advance project delivery method research, it is recommended that future studies be directed toward determining better identification and quantification of the factors that influence cost, quality, and time performance of the projects under study.

First and foremost is the need for research to determine the key data collection points required to adequately measure the performance of public school construction along with the development of a common data collection method and database. The current study and others have determined that the lack of a cohesive public school construction dataset is a barrier to the pursuit of knowledge and solutions to problem issues. Currently, data are not uniformly collected or reported in districts across the four states included within this study and thus, development of a shared database is not possible. Development of a common data collection method and database would be useful for all future studies employed to assist the education system with the construction of public schools.

Future research related to public school construction should include the value analysis of high performance designs, materials, and equipment suitable for energy efficient and sustainable building approaches such as LEED. Life cycle cost considerations and discussions of energy savings are prevalent across all media and throughout the design and construction industries. Research into the utilization of high performance mechanical, plumbing, and electrical equipment or interior and exterior materials in order to reduce energy and life cycle costs would be beneficial to those involved with construction and operation of public schools. Furthermore, life cycle cost performance analysis included in future studies of these projects may enable those involved with construction of public schools to apply quantifiable measures to the expected value adding benefits.

Additional research should also be directed at determining the issues having the greatest influence on public school construction complexity and the measures at which those issues must be present in order to achieve economical utilization of the CM at-Risk method. Based on the results of the current research, if only one third of the more than $1.3 billion in school projects completed with the CM at-Risk method had been completed utilizing Design-Bid-Build, the cost reductions would have exceeded $100 million. Development of a systematic approach to determine the proper school projects for which CM at-Risk or other collaborative methods should be utilized would be of great value to district construction managers and other public school decision makers. The research effort may require a case study approach of a small number of very similar projects in order to increase the depth of understanding and determine relational aspects and subtle differences that contribute to the complexity of public school construction projects.

Other opportunities for research involve utilization of prototypical school project designs and or standardized materials and equipment in order to improve performance across all metrics. The prototype issue was mentioned by district managers during the data collection process and the performance characteristics of this and other standardized materials and construction processes should be explored.

Additionally, due to the inclusion of a wide variety of project types and sizes included within the Konchar (1997) and Konchar and Sanvido (1998) studies and the attenuating affect this has on their results, an excellent opportunity exists for research similar to the current study targeted at the healthcare or other singular industries. It is of primary importance for those in decision-making capacities within those industries to receive empirical project performance results determining the levels at which their projects may be benefitting from collaborative construction methods.

And finally, there are a number of studies that could be accomplished at the district level that would benefit the public and the educational system. For example, in regard to the discussion of CM at-Risk projects receiving more time extensions than Design-Bid-Build projects, additional research is required at the district level in order to determine whether statistically significant differences actually exist and what the specific causes of those differences are. Issues of a wider concern require research at the state, regional, or national level.

6.6 Conclusion

The purpose of this research was to provide current, statistically significant, empirical evidence defining the comparative performance attributes of the most widely utilized project delivery methods of Design-Bid-Build and CM at-Risk in the construction of public school projects. The results of this study have provided conclusive evidence that the collaborative delivery method of CM at-Risk is capable of providing improved levels of product and service quality. However, these benefits will come at a significant increase in construction and project costs, indicating that a value assessment will be required for project delivery method selection. Furthermore, evidence has been provided that the Design-Bid-Build method has the ability to produce projects at product and service quality levels that are satisfactory to district construction managers employing this method, with the added benefit of the noted substantial cost reductions.

This research built on the foundation of research provided by the work of Konchar (1997), Sanvido and Konchar (1998), Williams (2003), and the current efforts of Kenig (2011) and the Associated General Contractors of America toward defining project delivery methods and their attributes. The work and evidence provided by this study serve to close the gap between the existing body of knowledge and that required to serve decision makers responsible for both the regulation and implementation of project delivery methods for public school projects. The results will aid policy makers as they formulate statutes that encourage utilization of the most appropriate methods based on the expectations of the districts and their constituents. The evidence will also assist district construction managers and others at the local level as they work to select the most appropriate delivery methods to fit the situational aspects encountered with construction of public schools in their individual districts.

The fact that collaborative work can produce beneficial results is without question. Those having the responsibility of serving the needs of the public have the duty to procure and deliver projects in the most efficient and effective manner, which requires policies and procedures designed to meet that need. CM at-Risk has proved to be a collaborative method that can provide beneficial results when utilized for the construction of public schools under the proper conditions. This method is a viable alternative to Design-Bid-Build for the construction of public schools and should be made available to those in a public school decision-making capacity.

APPENDICES

Appendix A

Project Delivery Method Comparison Chart

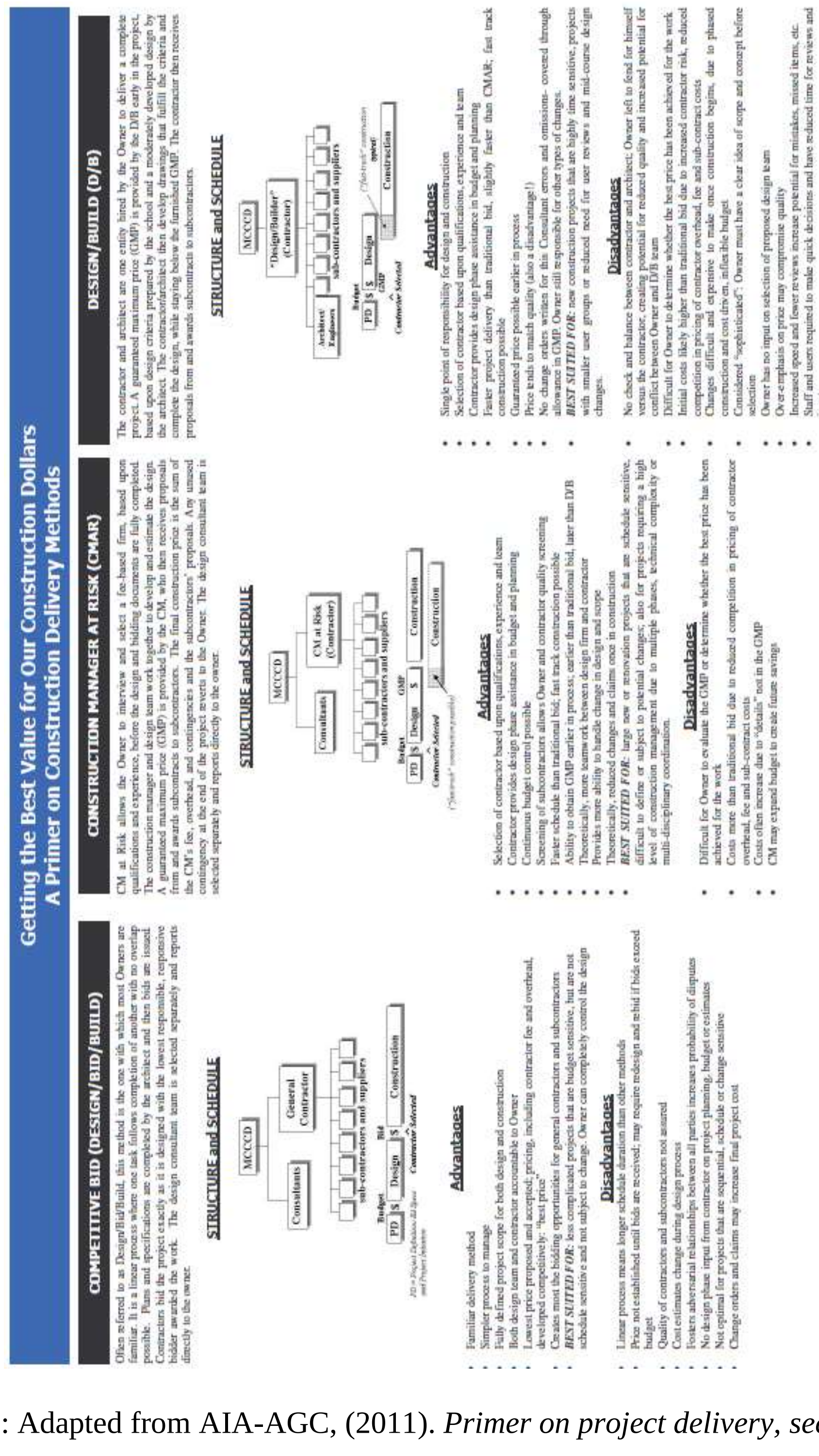


Figure A-1: Adapted from AIA-AGC, (2011). *Primer on project delivery, second edition.*

Appendix B

Research Survey Instrument

Clemson University Research

Informed Consent

A Study of Project Delivery Methods for the Construction of Public Schools

Description of the Study

My name is Noel Carpenter and I am a PhD candidate working with Dr. Dennis Bausman, the principal investigator for this research project. This valuable research will serve to benefit the public by providing information that will assist public officials in their efforts to execute policies that encourage utilization of the appropriate project delivery methods for public construction projects while empowering owners and other decision makers to confidently make informed project delivery decisions.

This survey is being distributed to public school administrators responsible for the construction of new schools across the states of South Carolina, North Carolina, Florida, and Georgia. At this point in the research, I am requesting your assistance with the completion of the attached survey instrument. The survey should take less than 30 minutes based on your access to public school construction project information. I appreciate your assistance and thank you in advance for providing the vital project information requested.

Choosing to Be in the Study

You do not have to be in this study. You may choose not to take part and you may choose to stop taking part at any time. Please contact me directly at 678-758-3344 or noelc123@gmail.com if you have any questions regarding the questionnaire or if additional information about the research effort is required.

If you have any questions or concerns about your rights in this research study, please contact the Clemson University Office of Research Compliance (ORC) at 864-656-6460 or irb@clemson.edu. If you are outside of the Upstate South Carolina area, please use the ORC's toll-free number, 866-297-3071.

Consent

We will do everything we can to protect your privacy and confidentiality. We will not tell anybody outside of the research team that you were in this study or what information we collected about you in particular.

Print Consent Form

I have read the informed consent form above and have been allowed to ask any questions I might have.

I agree to take part in this study.

- Yes
- No

Project Demographics

It is the intent of this survey to obtain information regarding your perceptions of the Project Delivery Methods utilized by your district. Please respond to **all questions** throughout this survey **based on your knowledge and perceptions** of the **recently completed public school facility project for which you have previously submitted project data.**

You will have the opportunity to complete more than one survey if data from multiple projects has been submitted.

Figure B-1: Research Survey Instrument.

Please enter the **project information** for the **public school** about which *you intend to provide survey data.*

Public School Name

School District

City

State

Please select the **type of public school** that *best represents* **this project.**

High School	Middle School or Junior High School	Elementary School	K-8 School	Other, please list in the space provided

Did you *utilize an outside agency/firm* to perform **Construction Management duties** (CM Agent, Agency, etc.) on **this project?**

- Yes
- No

Project Delivery and Procurement

Does your district **regularly utilize more than one** type of **Project Delivery Method** for the construction of public school facilities in your district?

- Yes
- No

Please select the **Project Delivery Method** that *best represents the one utilized* on **this project.**

- Design Bid Build
- CM at-Risk
- Multi-Prime
- Design Build
- Other, please list in the space provided

Utilizing the two options below, **please select** the **Procurement Method** that *best represents the one utilized* on **this project.**

Competitive Bid	Qualifications Based Selection

Figure B-2: Research Survey Instrument.

Please select the **Qualifications Based Selection Method** that *most closely represents* the method **utilized on this project.**

- ○ Qualifications Based Selection (Fees & Total Cost are **NOT** part of the selection criteria)
- ○ Best Value, Fees (**Fees** are a part of the selection criteria)
- ○ Best Value, Fees and Total Cost (**Fees & Total Cost** are part of the selection criteria)

Project Quality

Please rate your level of satisfaction with the **Quality of the Workmanship** provided by the **Construction Team** on **this project.**

	Very Dissatisfied	Dissatisfied	Satisfied	Very Satisfied	Don't Know
Workmanship Overall	○	○	○	○	○
Workmanship on Building Exterior	○	○	○	○	○
Workmanship on Building Interior	○	○	○	○	○
Workmanship on Heating and Air Conditioning System	○	○	○	○	○
Workmanship on Plumbing System	○	○	○	○	○
Workmanship on Lighting System	○	○	○	○	○
Warranty and Callbacks	○	○	○	○	○

Please list and rate your level of satisfaction with any other **Quality of Workmanship** characteristics provided by the **Construction Team** that you feel are important in the space provided.

Construction Team Service Quality

Please rate your level of satisfaction with the **Quality of the Construction Team Management Services** on **this project.**

	Very Dissatisfied	Dissatisfied	Satisfied	Very Satisfied	Don't Know
Overall Management	○	○	○	○	○
Construction Planning	○	○	○	○	○
Communications	○	○	○	○	○
Cooperation	○	○	○	○	○
Project Cost Control	○	○	○	○	○
Project Schedule Control	○	○	○	○	○
Building Quality Control	○	○	○	○	○

Figure B-3: Research Survey Instrument.

Please list and rate your level of satisfaction with the **Quality** of any other **Construction Team Management Services** that you feel are important in the space provided.

Design Team Service Quality

Please rate your level of satisfaction with the **Quality** of the **Design Team Professional Services on this project.**

	Very Dissatisfied	Dissatisfied	Satisfied	Very Satisfied	Don't Know
Captured and Translated Owner Vision					
Complete Construction Documents					
Clearly Defined Construction Documents					
Timely Responses					
Communications					
Cooperation					

Please list and rate your level of satisfaction with the **Quality** of any other **Design Team Professional Services** that you feel are important in the space provided.

Project Team Service Quality

Please rate your level of satisfaction with the **Quality of the Relationships** between the **Project Team Members (Owner, Architect, and Contractor)** on **this project.**

	Very Dissatisfied	Dissatisfied	Satisfied	Very Satisfied	Don't Know
Overall Relationship					
Communication					
Cooperation					
Collaboration					

Please list and rate your level of satisfaction with the **Quality** of any other **Project Team Relationship** characteristics that you feel are important in the space provided.

Figure B-4: Research Survey Instrument.

Project Team Experience

Please select the **number of projects** that best reflects ***your* Experience Level** *prior to being involved* on **this project.**

	None	1 or 2 Projects	3 or More Projects	Don't Know
Experience with School Construction Projects	◯	◯	◯	◯
Experience with Project Delivery Method Utilized on this Project	◯	◯	◯	◯
Experience with this Architect and Contractor Team	◯	◯	◯	◯
Experience Working with this Architect	◯	◯	◯	◯
Experience with this Contractor	◯	◯	◯	◯

Please select the number of projects that best reflects the **Contractor's Experience Level** *prior to being involved* on **this project.**

	None	1 or 2 Projects	3 or More Projects	Don't Know
Contractor's Experience with School Construction Projects	◯	◯	◯	◯
Contractor's Experience with Project Delivery Method Utilized on this Project	◯	◯	◯	◯

Please select the number of projects that best reflects the **Architect's Experience Level** *prior to being involved* on **this project.**

	None	1 or 2 Projects	3 or More Projects	Don't Know
Architect's Experience with School Construction Projects	◯	◯	◯	◯
Architect's Experience with Project Delivery Method Utilized on this Project	◯	◯	◯	◯

District Process

Do the **policies of your school district** *require the utilization* of a particular **Project Delivery Method**?

◯ Yes

◯ No

Figure B-5: Research Survey Instrument.

Please select the **level of importance** that the following factors have when the **selection of a Project Delivery Method** is *being considered* for the **construction of a public school project in your district**.

	Very Unimportant	Somewhat Unimportant	Somewhat Important	Very Important
Reduce the Overall Project Cost				
Control of Change Orders				
Reduce the Schedule Duration				
Control Schedule Overruns				
Improve Quality of the School Building				
Improve Quality of the Construction Process				
Improve Quality of the Project Team Relationships				
Control the Design Process				
Experience Level of the Owner				
Reduce Construction Disputes and Claims				

Please list and rate any additional issues that you feel are **important to consider** *when selecting the* **Project Delivery Method** for the construction of **public schools projects**.

Project Delivery Method

How **effective** do you feel the **Project Delivery Method** utilized on **this project** was at:

	Very Ineffective	Ineffective	Effective	Very Effective
Reducing Project Costs?				
Controlling Change Orders?				
Reducing Schedule Duration?				
Controlling Schedule Overruns?				
Improving the Quality of the School Building?				
Improving the Quality of the Construction Process?				
Improving the Relationships of the Project Team Members?				
Maintaining Control of the				

Figure B-6: Research Survey Instrument.

Design Process	○	○	○	○
Reducing Construction Disputes and Claims?	○	○	○	○

Please list and rate any additional **factors** and the level of **Effectiveness** that you feel the **Project Delivery Method** had on them during this project.

Claims Data

How many **construction disputes/claims** occurred on this project that **required mediation, arbitration, or litigation** to resolve?

None (0)	1 to 3	4 or more
○	○	○

What was the **overall cost impact** of these **disputes/claims** to the project?

$0	$1 to $50,000	$50,001 to $100,000	More than $100,000
○	○	○	○

Warranty and Callback Data

Are **records of warranty and callback issues** maintained for your new construction projects?

- ○ Yes
- ○ No

How many **warranty and callback issues** occurred during the **first year** after completion of this project?

0-2	3-5	6 or more
○	○	○

What was the **overall cost impact of these warranty and callback issues** to the project?

$0	$1 to $5,000	$5,001 to 10,000	More than $10,000
○	○	○	○

Contact Information

Thank you for completing the survey. In case we need to contact you in order to clarify a response or verify information, please provide your contact information in the spaces provided below.

Figure B-7: Research Survey Instrument.

Figure B-8: Research Survey Instrument.

Appendix C

Florida Report of Cost of Construction

FLORIDA DEPARTMENT OF EDUCATION
OFFICE OF EDUCATIONAL FACILITIES
2013 REPORT OF COST OF CONSTRUCTION

Complete the following information and return form to:
Kathy Dickey Email: kathy.dickey@fldoe.org
Office of Educational Facilities
Florida Department of Education
325 West Gaines Street, Room 824
Tallahassee, Florida 32399-0400
(850) 245-9248; FAX: (850) 245-9243

DATE SUBMITTED____________
CALENDAR YEAR____________
PREPARED BY____________(Print Name)
PHONE ____________
E-Mail____________

STEP 1: COLLEGE AND CAMPUS INFORMATION

COLLEGE NAME____________ OEF Project #________ - ________
CAMPUS NAME____________ BUILDING #____________
TITLE OF PROJECT____________

STEP 2: CONSTRUCTION PROJECT INFORMATION

MAJOR SPACE CATEGORY OF PROJECT (Choose One):

(01) Classrooms______ (02) Nonvocational Labs______ (03) Library/Study______ (04) Vocational Labs______ (05) Offices______
(06) Auditorium/Exhibition____ (07) Audiovisual____ (08) Student Services____ (09) Physical Education____ (10) Support Services____

PERCENT EACH SPACE CATEGORY REPRESENTS OF TOTAL PROJECT (Must Total 100%)

(01) Classrooms______ (02) Nonvocational Labs______ (03) Library/Study______ (04) Vocational Labs______ (05) Offices______
(06) Auditorium/Exhibition____ (07) Audiovisual____ (08) Student Services____ (09) Physical Education____ (10) Support Services____

PHASE III PLAN APPROVAL DATE____________ CONTRACT AWARD DATE____________
DATE CERTIFICATE OF OCCUPANCY ISSUED____________

STEP 3: BASELINE DATA **AMOUNT**

1. Number of Student Stations .... ________
2. Net Square Feet .... ________
3. Gross Square Feet .... ________
4. Cost Data
   a. **Cost to purchase site** .... $________
      This is the cost to purchase the site. If the site is an existing site, enter the cost of the site when originally purchased. If the site was donated, enter zero ("0").
   b. **Cost to make public utilities available at site (water, sewer, electric, gas, telephone)** .... $________
      This is the cost to bring water, sewer, power, gas and telephone to the site boundary and includes on-site water and on-site sewage treatment plants.
   c. **Cost to correct site drainage and/or construct a retention area** .... $________
      This refers to the additional cost incurred as a result of mandatory permits and/or inspections required by federal, state, or local agencies such as the Environmental Protection Agency, Department of Environmental Protection, water management districts, including local and state concurrency requirements to accommodate drainage problems at the site.
   d. **Cost to make public roads accessible** .... $________
      This is the cost to make the site accessible to the public, which may require sidewalks, additional turn lanes, traffic lights, or other requirements.

OEF 564CC
Rule 6A-2.0010, FAC

Effective December 2013

Figure C-1: Florida Department of Education (2013).

4. Cost Data (continued)

e. **Cost to make site free of environmental problems** .... $________
This refers to fees or additional costs incurred as a result of mandatory permits and/or inspections required by federal, state, or local agencies such as the Environmental Protection Agency, Department of Environmental Protection, water management districts, including local and state concurrency requirements.

f. **Cost to make as hurricane shelter and/or hurricane hardened** .... $________
This refers to the additional cost incurred as a result of mandatory hurricane shelter and/or hurricane hardening requirements due to location and designation by the Division of Emergency Management. Note: This amount should be deducted from Building Cost (Item J).

g. **Legal and administrative cost** .... $________
This refers to all legal and administrative fees paid to private attorneys, governmental agencies, and other professionals who are not architects or engineers, for services rendered (e.g., recording fees, doc stamps, clerk-of-the-works).

h. **Architect / Engineering fees** .... $________
This refers to the cost for professional architectural and engineering services performed in connection with planning, design, and construction of the facility. Incorporate all base service and additional authorization services.

i. **Site improvement cost (incidental to construction)** .... $________
This refers to the work that must be performed on a site from five feet away from building to site boundary. This includes the amount spent for finish grading, draining, seeding, planting, and preparing the site for use after the building has been constructed. Site improvement also refers to the cost of electrical transformers, sewer lift stations, and water, gas, and electric lines from five feet away from the building to the source of the utility at the site boundary.

j. **Building contract cost** .... $________
This refers to the total cost of building construction within five feet of building including all materials and supplies purchased by the board of trustees. All change order charges known at the time should also be added or deducted from the contract cost. Include built-in cabinets, mill work, and other furniture or equipment permanently fixed or attached to the building as part of building construction. Do not include cost for movable school furniture and equipment.

k. **Furniture and equipment** .... $________
This refers to all furniture and equipment required to make the facility operational on the first day of class. This includes, but is not limited to, student and teacher desks, computer equipment, laboratory equipment, library furniture, audio-visual equipment, library books required initially, and other equipment that a college would normally capitalize such as copy machines, etc. Equipment costs excluded from this definition are items such as interscholastic activity equipment, such as athletic or band uniforms. Additionally, textbooks, consumable supplies and non-capitalized laboratory supplies are excluded from this definition.

5. Building Cost (sum of lines 4g - 4k) .... $________

6. Cost per Student Station (divide line 5 by Line 1) .... $________

7. Educational Plant Total Cost (sum of lines 4a - 4k) (All plant-related costs) .... $________

STEP 4: SOURCE OF FUNDS	**AMOUNT EXPENDED**
____ PECO - 3-year priority list [s. 1013.64(4)(a), F.S.]	$________
____ Cooperative Use Facilities [s. 1013.52, F.S.]	$________
____ SBE Bond (COBI) [Article XII, Subsection 9(d), of the State Constitution, as amended]	$________
____ CO & DS [Article XII, Subsection 9(d), of the State Constitution, as amended]	$________
____ Other State Funds (Specify)________	$________
____ Other Local Funds (Specify)________	$________
____ Federal Funds (Specify)________	$________
____ Lease & Lease Purchase (COPs) [s.1013.15(4)(a), F.S.]	$________
******TOTAL** (must equal Total Project Cost above)	$________

I certify that all of the data and statements included in this report are, to the best of my knowledge and belief, true, complete, and correct.

____

College Official (**signature**) Telephone Number

OEF 564CC
Rule 6A-2.0010, FAC

Effective December 2013

Figure C-2: Florida Department of Education (2013).

Appendix D

Florida Department of Education Sample Database Information

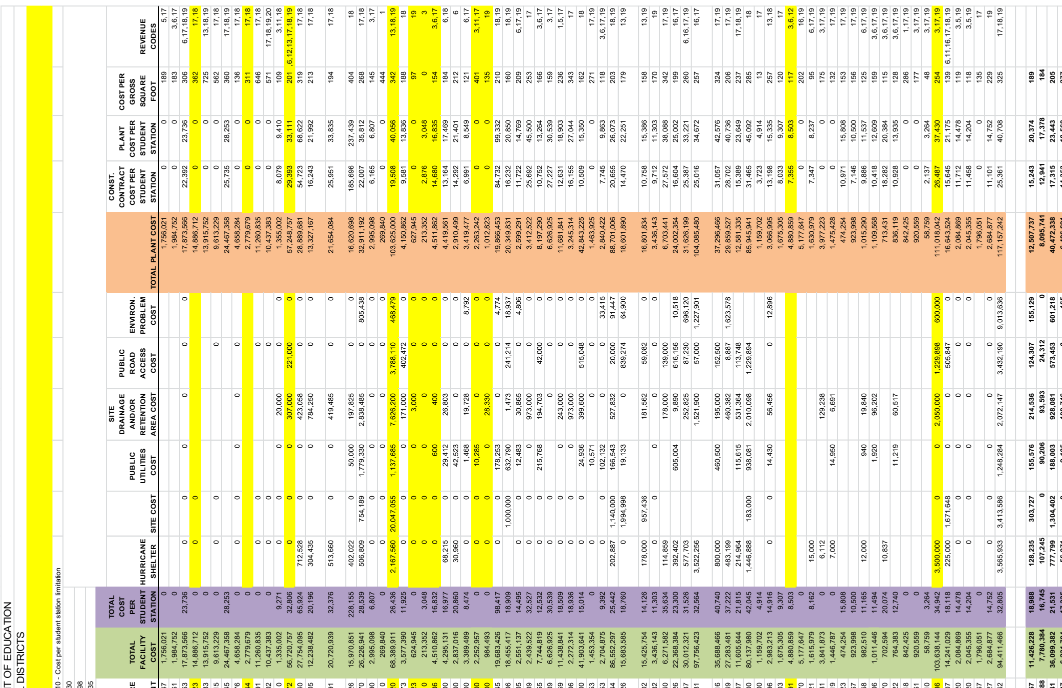


Figure D-1: Florida Department of Education (2013).

Appendix E

Introductory Letter to District Construction Manager

CLEMSON
College of ARCHITECTURE, ARTS AND HUMANITIES

August 15, 2013

Andy Taylor
District Construction Manager
Mayberry District Schools
1234 Main Street
Mayberry, NC 27123

Dear Mr. Taylor,

DEPARTMENT OF CONSTRUCTION SCIENCE AND MANAGEMENT

Clemson University
120 Lee Hall
Box 340507
Clemson, SC
29634-0507

P (864) 656-0181
F (864) 656-7542
clemson.edu/caah/csm

Following up on my phone message to your office today, please accept this letter of introduction regarding the public school (K-12) research project that I am conducting. My name is Noel Carpenter, and I am a PhD candidate working with Dr. Dennis Bausman, the principal investigator for the project. I have previously spoken with Steven Taynton, Chief, School Planning, North Carolina Department of Public Instruction, and he has offered the Department's support of this important research effort.

The purpose of this research is to compare the performance of Design-Bid-Build and Construction Manager at Risk project delivery methods and to determine which method is most effective and efficient for public school projects. This valuable research will serve to benefit the public by providing information that will assist public officials in their efforts to execute policies that encourage utilization of the appropriate project delivery methods, while empowering owners and other decision makers to confidently make informed project delivery decisions.

I appreciate your assistance and thank you in advance for providing the vital project information requested. At this point in the research, I am collecting and compiling preliminary project data on all new construction, public school (K-12) projects that have been completed in North Carolina, South Carolina, Georgia, and Florida after December 31, 2005. Please utilize the attached questionnaire to provide complete information on each project that has been completed within your district during this period. This information will then be utilized to establish the baseline data and to generate a list of facility managers to which a follow-up survey will be distributed.

Please contact me directly at 678-758-3344 or noelc123@gmail.com if you have any questions regarding the questionnaire or if additional information about the research effort is required.

Sincerely,

Noel Carpenter	Dennis C. Bausman, PhD, FAIC, CPC
PhD Candidate	Research Committee Chair
Planning, Design, and Built Environment	Professor and CSM Endowed Faculty Chair
Clemson University	Clemson University

Figure E-1: Introductory Letter to District Construction Manager.

Appendix F

Preliminary Project Data Collection Sheet

INSTRUCTIONS FOR COMPLETING THE: Preliminary Project Data Collection Sheet

PLEASE READ THIS IMPORTANT INFORMATION PRIOR TO COMPLETING THE DATA COLLECTION SHEET.

The purpose of this research is to compare the performance of the different project delivery methods and to determine which methods are most effective and efficient under differing circumstances. At this point in the research, I am collecting and compiling preliminary project data on all new construction, public school (K-12) projects that have been completed in North Carolina, South Carolina, Georgia, and Florida after December 31, 2005. This information will be utilized to establish the baseline data and to generate a list of Facility Construction Managers to which a more in-depth survey will be distributed.

Two of the primary aspects of our research will focus on comparisons of project costs and schedules across the varying project delivery methods. In order to accomplish this, I will need to determine the original and final construction contract sums along with the actual start, scheduled finish, and actual finish dates of the projects. And, in an effort to establish the legitimacy and credibility of the data across all projects, I will need to obtain a copy of the following documents: Construction Contract Agreement, Architect Contract Agreement, Notice to Proceed, Certificate of Substantial Completion, Final Construction Application for Payment, and Final Architect Billing.

Understanding that you and your staff are busy performing your regular duties, please notify me directly if I will need to schedule a visit to your office in order to sort the records, collect the data, and make copies of these important documents.

I appreciate your assistance and thank you in advance for providing the vital project information requested.

1. Please complete a separate data collection sheet for each new construction project
2. For the purpose of this study, project data will only be collected from:
   a. **NEW CONSTRUCTION (Greenfield or Replacement) PUBLIC SCHOOL (K-12) PROJECTS**
   b. **PROJECTS COMPLETED AFTER 2005**
3. For the purpose of this study, the following projects will not be included:
   a. Additions, renovations, and remodeling projects
   b. Small, separate projects such as auditoriums, field houses, and stadiums
4. Construction Contract Sums include all costs for the construction of the school facility including general conditions, profit, and fees. The amounts entered on the form should be recorded directly as shown on the Original Contract or Final Application for Payment unless a change is required due to one of the following issues:
   a. For multi-prime contract situations, the sum of all Prime Contracts is the Construction Contract Sum
   b. Land purchases, demolition, and sitework are not included
   c. Furniture and equipment are not included
   d. Stadiums and Sewage Plants are not included
   e. Architect and Engineer Fees are not included
   f. Construction Management Agency/Owner's Representative Fees are not included
5. Please place an NA (not applicable) or other notes in the spaces required

Figure F-1: Preliminary Project Data Collection Sheet.

Preliminary Project Data Collection Sheet

NEW CONSTRUCTION, PUBLIC SCHOOL (K-12) PROJECTS COMPLETED AFTER 2005

Please complete a separate data collection sheet for each new construction project.

Your Name:		Your Phone:	
Your State:	(NC, SC, GA, FL)	Date of Collection:	(Today's Date)
District/County Name:		District/County Number:	
Project/School Name:		Project/School Number:	
Project Type:	(Elementary, Middle, High, Other)	Project Size:	SF (Gross School Square Footage)
Project Delivery Method:	(Design-Bid-Build, Design-Build, CM@Risk)	Number of Students:	(Designed Student Capacity)
Original Construction Contract Sum:	$ (From Construction Contract)	Final Construction Contract Sum:	$ (From Final Application for Payment)
Original Architect Contract Sum or %:	$ (From Architect Contract)	Final Architect Contract Sum:	$ (From Final Billing)
Original Project Start Date:	(From Notice to Proceed)	Scheduled Project Completion Date:	(From Construction Contract)
Actual Project Completion Date:	(From Certificate of Substantial Completion)		

Project Team Contact Information

Contractor Firm:		Contractor Contact:	
Contractor Email:		Contractor Phone:	
Architect Firm:		Architect Contact:	
Architect Email:		Architect Phone:	
Owner:		Owner Contact:	
Owner Email:		Owner Phone:	
Owner's Rep:		Owner's Rep Contact:	
Owner's Rep Email:		Owner's Rep Phone:	

Figure F-2: Preliminary Project Data Collection Sheet.

Appendix G

Konchar (1997) Survey Instrument

PROJECT DELIVERY SYSTEM SURVEY

THE CONSTRUCTION INDUSTRY INSTITUTE
THE PENNSYLVANIA STATE UNIVERSITY

INSTRUCTIONS

Penn State has been selected to conduct a national survey of the three principal project delivery systems in the U.S. today. Please help us by completing the survey for at least one project you have completed in the last 5 years in the U.S. You may submit up to ten. At your request we will provide you a copy of the survey results.

Each survey form should be coordinated by your Project Manager. Thorough responses to survey sections 1 to 5 are the most critical to this study. Other sections are important to explain the reasons for the measured differences.

Upon receipt of your data, Penn State will number each copy, remove company identification, and remove project identification. The information you provide will be kept in strict confidentiality.

Please return the completed questionnaire by mail or fax before Dec. 31, 1996 to:

Dr. Victor E. Sanvido, Dept. of Architectural Engineering, Penn State University, 104 Engineering Unit "A", University Park, PA 16802-1416
Fax: (814) 863-4789 Phone: (814) 865-2869

DEFINITIONS

Design Bid Build is a traditional process in the US construction industry where the owner contracts separately with a designer and a contractor. The owner normally contracts with a design company to provide "complete" design documents. The owner or his/her agent then solicits fixed price bids from contractors to perform the work. One contractor is usually selected and enters into an agreement with the owner to construct a facility in accordance with the plans and specifications.

Design Build is an agreement between an owner and a single entity to perform both design and construction under a single design build contract. Portions or all of the design and construction may be performed by the entity or subcontracted to other companies.

In **CM at Risk,** the owner contracts with a design company to provide a facility design. The owner separately selects a contractor to perform construction management services and construction work in accordance with the plans and specifications for a fee. The contractor usually has significant input in the design process and generally guarantees the maximum construction price.

Figure G-1: Konchar (1997) Survey Instrument.

SECTION I: PROJECT CHARACTERISTICS

Project name: Project location: ______________

Project executive/ respondent who provided data: ______________

Phone number: ______________

Company name: ______________

O Owner O Design-Builder O Architect/Designer O Contractor

Please mark the appropriate oval for project type:

O Office	O Light Manuf.	O Micro-Elec.	O Parking
O Schools	O Warehouse	O Pharmaceutical	O Other
O Recreation	O Grocery	O Food Proc.	
O Housing	O Postal	O R & D	

Building gross square footage sf No of floors ______________

Percentage of the project: Renovation % New construction ______ %

SECTION II: PROJECT DELIVERY SYSTEM

Mark the appropriate oval for the project delivery system which best suits that used on your project:

Construction Management @ Risk	O
Design-Build	O
Design-Bid-Build	O

Mark the appropriate oval for the commercial terms used for the design-builder or designer and contractor: (*If Cost plus, please state fee type in blank provided*)

Design-Builder	O Lump Sum	O Cost Plus___Fee	O GMP
Architect/Designer	O Lump Sum	O Cost Plus___Fee	O GMP
Contractor	O Lump Sum	O Cost Plus___Fee	O GMP

SECTION III: PROJECT SCHEDULE PERFORMANCE

Please provide the following **schedule** information:

Item	As Planned (mm/dd/yy)	As Built (mm/dd/yy)
Date Project was Advertised		
Design Start Date (Notice to Proceed)		
Construction Start Date (Notice to Proceed)		
Construction End Date (Substantial Completion)		

Figure G-2: Konchar (1997) Survey Instrument.

SECTION IV: PROJECT COST PERFORMANCE

What were the following total **project costs**. Indicate whether estimated (E) or actual (A). Please deduct all property costs; owner costs; costs of installed process or manufacturing equipment; furnishings, fittings and equipment; or items not a cost of the base building.

Stage / Cost	Design Costs	Construction Costs	Total Project Costs
Budget			
Contract Award			
Final Cost			

Please estimate the cost of site work (work done outside the footprint of the building) as the percent (%) of final construction costs: ________________ %

SECTION V: PROJECT QUALITY PERFORMANCE

If you are the owner, please complete section V. If not, please provide the owner's name or point of contact ______________________________
and phone number ____________________, *and proceed to survey section VI.*

Mark the appropriate ovals to evaluate the **quality** of the building:

Difficulty of facility startup:
O High   O Medium   O Low

Number and magnitude of call backs:
O High   O Medium   O Low

Operation/maintenance cost for building/site:
O High   O Medium   O Low

Did the quality of envelope/roof/structure/foundation meet your expectations?
O Exceeded   O Yes   O No

Did the quality of interior space/layout meet your expectations?
O Exceeded   O Yes   O No

Did the quality of environmental systems (light,HVAC) meet your expectations?
O Exceeded   O Yes   O No

Did the quality of process equipment/layout meet your expectations?

Figure G-3: Konchar (1997) Survey Instrument.

SECTION VI: PROJECT TEAM CHARACTERISTICS

Mark the appropriate oval for each of the following attributes of your project team:

Project team selection:

O Open Bidding	O Prequalified Bidding
O Negotiated Contract	O Contract Documents

Ability to restrain contractor pool:		O High	O Low
Was there a pool of qualified contractors?		O Yes	O No

What percentage of design was complete when the construction entity joined the project team? ________ %.

Individual experience of members with similar facilities:

Owner's Representative	O Excellent	O Limited	O None
Design-Builder	O Excellent	O Limited	O None
Architect/Designer	O Excellent	O Limited	O None
Contractor	O Excellent	O Limited	O None
Subcontractors	O Excellent	O Limited	O None

Individual experience of members using your project's delivery system:

Owner's Representative	O Excellent	O Limited	O None
Design-Builder	O Excellent	O Limited	O None
Architect/Designer	O Excellent	O Limited	O None
Contractor	O Excellent	O Limited	O None
Subcontractors	O Excellent	O Limited	O None

Team's prior experience as a unit:	O Excellent	O Limited	O None
Project team communication:	O Excellent	O Limited	O None
Project team chemistry:	O Excellent	O Adequate	O Poor
Owner type:	O Public	O Private	
Owner-project team relationship:	O First Time	O Partnering	O Repeat
Owner representative's capability:	O Excellent	O Adequate	O Poor
Owner's ability to define scope:	O Excellent	O Adequate	O Poor
Owner's ability to make decisions:	O Excellent	O Adequate	O Poor
Project complexity:	O High	O Average	O Low
Regulatory/legal constraints:	O Many	O Few	O None
Onerous contract clauses:	O Numerous	O Several	O None
Labor type:	Union ___%	Non Union ___%	
Contractor's work split:	Direct Hire ___%	Subcontracted ___%	

Figure G-4: Konchar (1997) Survey Instrument.

SECTION VII: PROJECT DATA

For the following items please mark the appropriate oval in each category to identify the appropriate systems and/or descriptors that apply to your project:

FOUNDATION:

- O Slab on grade with spread footings
- O Caissons, piles or slurry walls
- O Mat foundation
- O Other:

STRUCTURE:

- O Pre-engineered metal building
- O Bar joists or precast planks on bearing walls
- O Steel frame and metal deck
- O Precast concrete frame and decks
- O Cast-in-place concrete structure
- O Complex geometry/mixed framing types
- O Other:

ARCHITECTURAL INTERIOR FINISHES:

- O Minimal (eg. warehouse, factory)
- O Corporate office
- O Standard commercial office
- O Clean room environment
- O Monumental building finishes (e.g. marble)
- O Other:

EXTERIOR ENCLOSURE:

- O All glass curtain wall
- O CMU, brick, or stone
- O Cast-in-place exterior walls
- O Metal panels
- O Precast panels
- O Other:

ROOFING:

- O Asphalt shingle
- O Built-up /single-ply membrane
- O Other:
- O Steep roof with tile/slate
- O Architectural standing seam

HEATING/COOLING:

- O Roof top units
- O Central plant
- O Split system
- O Heating only
- O Cooling only
- O Ventilation only
- O Other:

ELECTRICAL:

- O Uninteruptable power supply
- O General lighting and computer use
- O Process equipment loads
- O Electric heat
- O Intensive computer use
- O Security system

CONTROLS:

- O Direct digital controls
- O Other:
- O Pneumatic controls

SITE:

- O Urban
- O Suburban
- O Rural
- O Existing utilities
- O Existing roads
- O Mass excavation
- O Other:

Figure G-5: Konchar (1997) Survey Instrument.

SECTION VIII: PROJECT SUCCESS CRITERIA

Please list the criteria your organization uses to measure success and then mark the appropriate oval to rank each as it applied to your project:

1. ____________________
   O Excellent O Average O Poor
2. ____________________
   O Excellent O Average O Poor
3. ____________________
   O Excellent O Average O Poor
4. ____________________
   O Excellent O Average O Poor
5. ____________________
   O Excellent O Average O Poor

Mark the appropriate oval to rate the overall success of the project:
O Excellent O Average O Poor

SECTION IX: LESSONS LEARNED

If the answers to any of the following are yes, please list examples or reasons in the space below each question.

List any lessons you learned on this project about the project delivery system:

Could this project have been better delivered or more successful? How?

Did the delivery system enhance or hinder your ability to perform? How?

Did the project meet the intended needs?

Describe any unique features about this building that influenced its cost, schedule, or quality.

Figure G-6: Konchar (1997) Survey Instrument.

Appendix H

Institutional Review Board Approval Letters

From: Laura Moll
To: herberc@clemson.edu
Subject: Your research study entitled "Project Delivery Methods: Phase I – collection of project data on recently constructed schools
Date: Wednesday, September 05, 2012 4:16:00 PM
Attachments: image001.png

Dear Mr. Carpenter,

The Clemson University Office of Research Compliance (ORC) has determined that the project identified above **does not involve human subjects** as defined in the Federal regulations governing the protection of human subjects in research [45 CFR 46.102(f)] and is, therefore, **not subject to IRB review.**

As per our conversation this afternoon, at this time, this project will not involve either "intervention or interaction" with living individuals, or the collection or use of "identifiable private information" about living individuals. Therefore, IRB review is not required.

Please remember that we also determined that Phases II and III of your study ***will*** involve human subjects and, therefore, ***will*** require IRB review. As we discussed, Phase II will involve telephone interviews with architects who have built schools, and Phase III will involve surveying architects who have built schools. I look forward to working with you again when you are reading for the IRB review of these phases of your study.

Please contact this office again if there are any changes to this Phase I that might bring it under the purview of the IRB. It is the responsibility of the ORC to determine whether any specific research project falls within the definition of research with human subjects, as provided by Federal regulations and institutional policy.

Thank you for contacting us to check on whether your project required IRB review and approval.

Good luck with this project and please feel free to contact me if you have any questions.

Best,

Laura :-)

~~~~~~

Laura A. Moll, M.A., CIP
IRB Administrator
Office of Research Compliance
223 Brackett Hall
Clemson University
Clemson, SC 29634-5704
lmoll@clemson.edu
Phone: 864-656-6460

Figure H-1: Institutional Review Board Approval Letters
~~~~~~

From: Nalinee Patin [mailto:NPATIN@clemson.edu]
Sent: Friday, March 15, 2013 11:16 AM
To: Dennis Bausman
Cc: noelc123@gmail.com
Subject: Validation of IRB2013-074: A Comparative Analysis of the Design-Bid-Build...

Dear Dr. Bausman,

The chair of the Clemson University Institutional Review Board (IRB) validated the protocol identified above using exempt review procedures and a determination was made on **March 15, 2013**, that the proposed activities involving human participants qualify as **Exempt** from continuing review under category **B2** based on federal regulations 45 CFR 46. You may begin this study.

Please remember that the IRB had to review all changes to this research protocol before initiation. You are obligated to report any unanticipated problems involving risks to subjects, complications, and/or any adverse events to the Office of Research Compliance (ORC) immediately. All team members are require to review the "Responsibilities of Principal Investigators" and the "Responsibilities of Research Team Members" available at http://www.clemson.edu/research/compliance/irb/regulations.html.

Pam Brown, in the Office of Sponsored Programs, is being copied on this notice to enhance communication among all of us. We ask that you notify the ORC when your study is complete or if terminated. Please let us know if you have any questions and use the IRB number and title in all communications regarding this study.

Good luck with your study.

All the best,
Nalinee

Nalinee D. Patin
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Figure H-2: Institutional Review Board Approval Letters

Appendix I

School Planning and Management: 2012 Median Public School Costs

REGION 4 MEDIANS NEW SCHOOLS *(KY, NC, SC, TN)*

	Elementary	Middle	High
$/sq. ft.	$200.20	$204.11	$189.00
$/student	$29,000	$37,976	$36,311
Sq. ft./student	162.5	168.1	191.3
Students	510	710	1,188
Size (sq. ft.)	80,000	115,000	217,000
Total cost ($000)	$15,000	$26,500	$36,600

The median elementary school in Region 4 cost $200 per square foot or $29,000 for each of 510 students. The median middle school houses 710 students in 115,000 square feet. The region's median new high school housed 1,188 students and cost $36.6 million.

REGION 5 MEDIANS NEW SCHOOLS *(AL, FL, GA, MS)*

	Elementary	Middle	High
$/sq. ft.	$166.67	$165.53	$163.68
$/student	$23,567	$32,297	$32,923
Sq. ft./student	139.9	186.0	193.2
Students	461	828	1,008
Size (sq. ft.)	65,500	120,257	235,000
Total cost ($000)	$12,000	$22,000	$38,518

The median elementary school in Region 5 cost $166.67 per square foot or $23,567 for each of the 461 students. The median high school cost $38.5 million and encompassed 235,000 square feet. Middle schools were half that size and housed 180 fewer students.

Figure I-1: Abramson, P. (2013). 2013 Annual School Construction Report

Appendix J

RS Means Cost Estimates for 2012 Charlotte Public Schools

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RSMeans QuickCost Estimator

Project Title:	Sample Charlotte Elementary
Model:	School, Elementary
Construction:	Face Brick with Concrete Block Back-up / Steel Frame
Location:	CHARLOTTE, NC
Stories:	1
Story Height (l.f.):	15
Floor Area (s.f.):	110,000
Data Release:	Year 2012 Quarter 3
Wage Rate:	Union
Basement:	Not Included

Costs are derived from a building model with basic components. Scope differences and market conditions can cause costs to vary significantly.

Cost Ranges	Low	Med	High
Total:	$8,730,000	$9,700,000	$12,125,000
Contractor's Overhead & Profit:	$2,182,500	$2,425,000	$3,031,250
Architectural Fees:	$764,100	$849,000	$1,061,250
Total Building Cost:	**$11,676,600**	**$12,974,000**	**$16,217,500**

Do You Need a More Comprehensive Estimate With Current Cost Data and Your Own Detailed Project Specifications?

Access the Custom Cost Estimator, a paid subscription service, to reference a comprehensive library of square foot models updated and localized for the United States to create a customized online estimate specific to your individual project! - **All from RSMeans, *The Industry Source!***

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Important note: *These costs are not exact and are intended only as a preliminary guide to possible project cost. Actual project cost may vary greatly depending on many factors. RSMeans uses diligence in preparing the information contained here. RSMeans does not make any warranty or guarantee as to the accuracy, correctness, value, sufficiency or completeness of the data or resulting project cost estimates. RSMeans shall have no liability for any loss, expense or damage arising out of or in connection with the information contained herein.*

Figure J-1: Reed Business Information. RS Means.com (2013)

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RSMeans QuickCost Estimator

Project Title:	Sample Middle
Model:	School, Jr High, 2-3 Story
Construction:	Face Brick with Concrete Block Back-up / Steel Frame
Location:	CHARLOTTE, NC
Stories:	2
Story Height (l.f.):	15
Floor Area (s.f.):	165,000
Data Release:	Year 2012 Quarter 3
Wage Rate:	Union
Basement:	Not included

Costs are derived from a building model with basic components. Scope differences and market conditions can cause costs to vary significantly.

Cost Ranges	Low	Med	High
Total:	$13,797,900	$15,331,000	$19,163,750
Contractor's Overhead & Profit:	$3,449,700	$3,833,000	$4,791,250
Architectural Fees:	$1,207,350	$1,341,500	$1,676,875
Total Building Cost:	**$18,454,950**	**$20,505,500**	**$25,631,875**

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Figure J-2: Reed Business Information. RS Means.com (2013)

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RSMeans QuickCost Estimator

Project Title:	**Sample High**
Model:	**School, High, 2-3 Story**
Construction:	**Face Brick with Concrete Block Back-up / Steel Frame**
Location:	**CHARLOTTE, NC**
Stories:	**2**
Story Height (l.f.):	**15**
Floor Area (s.f.):	**250,000**
Data Release:	**Year 2012 Quarter 3**
Wage Rate:	**Union**
Basement:	**Not included**

Costs are derived from a building model with basic components. Scope differences and market conditions can cause costs to vary significantly.

Cost Ranges	Low	Med	High
Total:	$19,664,550	$21,849,500	$27,311,875
Contractor's Overhead & Profit:	$4,916,250	$5,462,500	$6,828,125
Architectural Fees:	$1,720,800	$1,912,000	$2,390,000
Total Building Cost:	**$26,301,600**	**$29,224,000**	**$36,530,000**

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Important note: *These costs are not exact and are intended only as a preliminary guide to possible project cost. Actual project cost may vary greatly depending on many factors. RSMeans uses diligence in preparing the information contained here. RSMeans does not make any warranty or guarantee as to the accuracy, correctness, value, sufficiency or completeness of the data or resulting project cost estimates. RSMeans shall have no liability for any loss, expense or damage arising out of or in connection with the information contained herein.*

Figure J-3: Reed Business Information. RS Means.com (2013)

Appendix K

SAS Report of Means and Other Statistical Analysis

SAS Analysis by Project Delivery Method

Variable : ProjSize (ProjSize)

PDM	N	Mean	Std Dev	Std Err	Minimum	Maximum
CM @ Risk	51	144094	56117.1	7858	76305	285494
Design Bid Build	86	150695	72239.3	7789.8	61805	432000
Diff (1-2)		-6601.1	66723.9	11792.5		

PDM	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
CM @ Risk		144094	128311	159877	56117.1	46953.7	69757.9
Design Bid Build		150695		166183	72239.3	62822.1	85003.8
Diff (1-2)	Pooled	-6601.1	-29923.1	16720.9	66723.9	59625.6	75755.7
Diff (1-2)	Satterthwaite	-6601.1	-28498.9	15296.8			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	135	-0.56	0.5766
Satterthwaite	Unequal	125.35	-0.6	0.5519

	Equality of Variances			
Method	Num DF	Den DF	F Value	Pr > F
Folded F	85	50	1.66	0.0545

Variable: StudCap (StudCap)

PDM	N	Mean	Std Dev	Std Err	Minimum	Maximum
CM @ Risk	51	1041.8	396.8	55.5678	300	2000
Design Bid Build	86	1073.7	424.9	45.8154	446	3000
Diff (1-2)		-31.8785	414.7	73.2944		

PDM	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
CM @ Risk		1041.8	930.2	1153.4	396.8	332	493.3
Design Bid Build		1073.7	982.6	1164.8	424.9	369.5	499.9
Diff (1-2)	Pooled	-31.8785	-176.8	113.1	414.7	370.6	470.8
Diff (1-2)	Satterthwaite	-31.8785	-174.6	110.8			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	135	-0.43	0.6643
Satterthwaite	Unequal	110.93	-0.44	0.6589

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	85	50	1.15	0.6069

Variable: SFStud (SFStud)

PDM	N	Mean	Std Dev	Std Err	Minimum	Maximum
CM @ Risk	51	141.4	28.958	4.0549	97.1703	254.4
Design Bid Build	86	139.2	27.0296	2.9147	95.377	225
Diff (1-2)		2.1835	27.7594	4.9061		

PDM	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
CM @ Risk		141.4	133.3	149.5	28.958	24.2294	35.9971
Design Bid Build		139.2	133.4	145	27.0296	23.506	31.8056
Diff (1-2)	Pooled	2.1835	-7.5193	11.8862	27.7594	24.8063	31.517
Diff (1-2)	Satterthwaite	2.1835	-7.7247	12.0917			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	135	0.45	0.657
Satterthwaite	Unequal	99.405	0.44	0.6629

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	50	85	1.15	0.5689

Variable: CFOCCos (CFOCCos)

PDM	N	Mean	Std Dev	Std Err	Minimum	Maximum
CM @ Risk	51	26001207	10843975	1518460	11904560	58719306
Design Bid Build	86	20960467	11955144	1289156	7452144	53717311
Diff (1-2)		5040740	11556064	2042377		

PDM	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
CM @ Risk		26001207	22951289	29051124	10843975	9073253	13479909
Design Bid Build		20960467	18397279	23523655	11955144	10396662	14067593
Diff (1-2)	Pooled	5040740	1001546	9079933	11556064	10326699	13120318
Diff (1-2)	Satterthwaite	5040740	1094587	8986892			

Method	Variances	DF	t Value	Pr > |t|

Pooled	Equal	135	2.47	0.0148
Satterthwaite	Unequal	113.4	2.53	0.0128

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	85	50	1.22	0.4579

Variable: CFFCCos (CFFCCos)

PDM	N	Mean	Std Dev	Std Err	Minimum	Maximum
CM @ Risk	51	26101221	11014186	1542295	11404750	59823692
Design Bid Build	86	21280286	12327718	1329332	7849271	54993773
Diff (1-2)		4820935	11858202	2095776		

PDM	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
CM @ Risk		26101221	23003431	29199011	11014186	9215670	13691494
Design Bid Build		21280286	18637217	23923354	12327718	10720667	14506000
Diff (1-2)	Pooled	4820935	676136	8965735	11858202	10596694	13463353
Diff (1-2)	Satterthwaite	4820935	787641	8854230			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	135	2.3	0.023
Satterthwaite	Unequal	114.66	2.37	0.0196

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	85	50	1.25	0.3902

Variable: CFODCos (CFODCos)

PDM	N	Mean	Std Dev	Std Err	Minimum	Maximum
CM @ Risk	51	1139885	565541	79191.6	490715	2924746
Design Bid Build	86	1062762	633645	68327.7	376536	2989640
Diff (1-2)		77123.5	609310	107687		

PDM	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
CM @ Risk		1139885	980824	1298946	565541	473194	703012
Design Bid Build		1062762	926908	1198615	633645	551043	745609
Diff (1-2)	Pooled	77123.5	-135849	290096	609310	544490	691787

Diff (1-2)	Satterthwaite	77123.5	-130063	284310

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	135	0.72	0.4751
Satterthwaite	Unequal	114.75	0.74	0.4624

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	85	50	1.26	0.3857

Variable: CFFDCoNo (CFFDCoNo)

PDM	N	Mean	Std Dev	Std Err	Minimum	Maximum
CM @ Risk	51	1311454	625183	87543.2	483229	3244528
Design Bid Build	86	1146085	759078	81853.5	397950	4934222
Diff (1-2)		165368	712427	125912		

PDM	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
CM @ Risk		1311454	1135618	1487289	625183	523097	777152
Design Bid Build		1146085	983339	1308832	759078	660124	893205
Diff (1-2)	Pooled	165368	-83646.5	414383	712427	636637	808863
Diff (1-2)	Satterthwaite	165368	-71901.2	402638			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	135	1.31	0.1913
Satterthwaite	Unequal	121.16	1.38	0.1702

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	85	50	1.47	0.1382

Variable: CFFDCos (CFFDCos)

PDM	N	Mean	Std Dev	Std Err	Minimum	Maximum
CM @ Risk	51	1335076	625158	87539.7	483229	3322989
Design Bid Build	86	1147268	769704	82999.3	197630	4943362
Diff (1-2)		187808	719562	127173		

PDM	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
CM @ Risk		1335076	1159248	1510905	625158	523076	777120

Design Bid Build		1147268	982244	1312293	769704	669365	905709
Diff (1-2)	**Pooled**	187808	-63700.6	439317	719562	643013	816963
Diff (1-2)	**Satterthwaite**	187808	-50990.9	426607			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	135	1.48	0.1421
Satterthwaite	Unequal	122.21	1.56	0.1221

	Equality of Variances			
Method	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Folded F	85	50	1.52	0.1122

Variable: CFOPCos (CFOPCos)

PDM	N	Mean	Std Dev	Std Err	Minimum	Maximum
CM @ Risk	51	27141092	11318282	1584876	12395276	60892480
Design Bid Build	86	22023229	12523951	1350492	7988002	56366176
Diff (1-2)		5117863	12091433	2136996		

PDM	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
CM @ Risk		27141092	23957774	30324410	11318282	9470109	14069509
Design Bid Build		22023229	19338088	24708369	12523951	10891319	14736907
Diff (1-2)	**Pooled**	5117863	891542	9344184	12091433	10805113	13728155
Diff (1-2)	**Satterthwaite**	5117863	992876	9242850			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	135	2.39	0.018
Satterthwaite	Unequal	113.71	2.46	0.0155

	Equality of Variances			
Method	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Folded F	85	50	1.22	0.4408

Variable: CFFPCosN (CFFPCosN)

PDM	N	Mean	Std Dev	Std Err	Minimum	Maximum
CM @ Risk	51	27412675	11557285	1618344	11887978	63068221
Design Bid Build	86	22426371	13006076	1402481	8385101	57408628
Diff (1-2)		4986304	12489098	2207278		

PDM	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
CM @ Risk		27412675	24162136	30663213	11557285	9670085	14366608
Design Bid Build		22426371	19637862	25214879	13006076	11310593	15304222
Diff (1-2)	Pooled	4986304	620987	9351621	12489098	11160474	14179649
Diff (1-2)	Satterthwaite	4986304	744463	9228144			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	135	2.26	0.0255
Satterthwaite	Unequal	115.11	2.33	0.0216

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	85	50	1.27	0.3674

Variable: CFFPCos (CFFPCos)

PDM	N	Mean	Std Dev	Std Err	Minimum	Maximum
CM @ Risk	51	27436298	11559487	1618652	11887978	63146681
Design Bid Build	86	22427554	13020281	1404013	8390064	57408628
Diff (1-2)		5008743	12499168	2209058		

PDM	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
CM @ Risk		27436298	24185139	30687456	11559487	9671928	14369346
Design Bid Build		22427554	19636000	25219108	13020281	11322946	15320937
Diff (1-2)	Pooled	5008743	639907	9377580	12499168	11169472	14191082
Diff (1-2)	Satterthwaite	5008743	764483	9253004			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	135	2.27	0.025
Satterthwaite	Unequal	115.19	2.34	0.0211

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	85	50	1.27	0.3637

Variable: CFCCGP (CFCCGP)

PDM	N	Mean	Std Dev	Std Err	Minimum	Maximum
CM @ Risk	51	0.318	4.8694	0.6818	-9.4776	12.114

Design Bid Build	86	1.2549	3.234	0.3487	-6.6012	19.5779
Diff (1-2)		-0.9369	3.92	0.6928		

PDM	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
CM @ Risk		0.318	-1.0516	1.6875	4.8694	4.0742	6.053
Design Bid Build		1.2549	0.5615	1.9483	3.234	2.8124	3.8054
Diff (1-2)	Pooled	-0.9369	-2.3071	0.4332	3.92	3.503	4.4507
Diff (1-2)	Satterthwaite	-0.9369	-2.4621	0.5882			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	135	-1.35	0.1785
Satterthwaite	Unequal	76.5	-1.22	0.2249

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	50	85	2.27	0.0009

Variable: CFPCNGP (CFPCNGP)

PDM	N	Mean	Std Dev	Std Err	Minimum	Maximum
CM @ Risk	51	0.9403	4.9006	0.6862	-7.8712	13.0633
Design Bid Build	86	1.4891	3.4022	0.3669	-6.3467	20.865
Diff (1-2)		-0.5489	4.0228	0.711		

PDM	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
CM @ Risk		0.9403	-0.4381	2.3186	4.9006	4.1004	6.0918
Design Bid Build		1.4891	0.7597	2.2186	3.4022	2.9587	4.0034
Diff (1-2)	Pooled	-0.5489	-1.955	0.8572	4.0228	3.5948	4.5673
Diff (1-2)	Satterthwaite	-0.5489	-2.0978	1			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	135	-0.77	0.4415
Satterthwaite	Unequal	78.877	-0.71	0.4826

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	50	85	2.07	0.003

Variable: CFPCGP (CFPCGP)

PDM	N	Mean	Std Dev	Std Err	Minimum	Maximum
CM @ Risk	51	1.039	4.9033	0.6866	-7.8712	13.2065
Design Bid Build	86	1.4526	3.5582	0.3837	-8.3501	20.865
Diff (1-2)		-0.4136	4.1081	0.726		

PDM	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
CM @ Risk		1.039	-0.34	2.4181	4.9033	4.1026	6.0952
Design Bid Build		1.4526	0.6898	2.2155	3.5582	3.0943	4.1869
Diff (1-2)	Pooled	-0.4136	-1.8495	1.0223	4.1081	3.671	4.6641
Diff (1-2)	Satterthwaite	-0.4136	-1.9784	1.1512			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	135	-0.57	0.5699
Satterthwaite	Unequal	81.433	-0.53	0.6004

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	50	85	1.9	0.0091

Variable: CFCUCost (CFCUCost)

PDM	N	Mean	Std Dev	Std Err	Minimum	Maximum
CM @ Risk	51	191.6	37.5285	5.255	91.1061	261.5
Design Bid Build	86	148.8	39.2481	4.2322	70.0376	289.3
Diff (1-2)		42.8156	38.6201	6.8256		

PDM	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
CM @ Risk		191.6	181	202.2	37.5285	31.4004	46.6508
Design Bid Build		148.8	140.4	157.2	39.2481	34.1317	46.1831
Diff (1-2)	Pooled	42.8156	29.3167	56.3145	38.6201	34.5116	43.8478
Diff (1-2)	Satterthwaite	42.8156	29.4424	56.1887			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	135	6.27	<.0001
Satterthwaite	Unequal	108.94	6.35	<.0001

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	85	50	1.09	0.7407

PDM	N	Mean	Std Dev	Std Err	Minimum	Maximum
CM @ Risk	51	1.039	4.9033	0.6866	-7.8712	13.2065
Design Bid Build	86	1.4526	3.5582	0.3837	-8.3501	20.865
Diff (1-2)		-0.4136	4.1081	0.726		

PDM	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
CM @ Risk		1.039	-0.34	2.4181	4.9033	4.1026	6.0952
Design Bid Build		1.4526	0.6898	2.2155	3.5582	3.0943	4.1869
Diff (1-2)	Pooled	-0.4136	-1.8495	1.0223	4.1081	3.671	4.6641
Diff (1-2)	Satterthwaite	-0.4136	-1.9784	1.1512			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	135	-0.57	0.5699
Satterthwaite	Unequal	81.433	-0.53	0.6004

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	50	85	1.9	0.0091

Variable: CFCUCost (CFCUCost)

PDM	N	Mean	Std Dev	Std Err	Minimum	Maximum
CM @ Risk	51	191.6	37.5285	5.255	91.1061	261.5
Design Bid Build	86	148.8	39.2481	4.2322	70.0376	289.3
Diff (1-2)		42.8156	38.6201	6.8256		

PDM	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
CM @ Risk		191.6	181	202.2	37.5285	31.4004	46.6508
Design Bid Build		148.8	140.4	157.2	39.2481	34.1317	46.1831
Diff (1-2)	Pooled	42.8156	29.3167	56.3145	38.6201	34.5116	43.8478
Diff (1-2)	Satterthwaite	42.8156	29.4424	56.1887			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	135	6.27	<.0001
Satterthwaite	Unequal	108.94	6.35	<.0001

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	85	50	1.09	0.7407

Folded F	50	85	2.2	0.0014

Variable: RPlanCDa (RPlanCDa)

PDM	N	Mean	Std Dev	Std Err	Minimum	Maximum
CM @ Risk	51	543.9	182	25.4793	300	1188
Design Bid Build	86	522.5	124.3	13.4012	330	850
Diff (1-2)		21.3279	148.3	26.2066		

PDM	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
CM @ Risk		543.9	492.7	595	182	152.2	226.2
Design Bid Build		522.5	495.9	549.2	124.3	108.1	146.2
Diff (1-2)	Pooled	21.3279	-30.5007	73.1564	148.3	132.5	168.4
Diff (1-2)	Satterthwaite	21.3279	-35.9862	78.6419			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	135	0.81	0.4172
Satterthwaite	Unequal	77.98	0.74	0.461

	Equality of Variances			
Method	Num DF	Den DF	F Value	Pr > F
Folded F	50	85	2.14	0.0019

Variable: ActCDa (ActCDa)

PDM	N	Mean	Std Dev	Std Err	Minimum	Maximum
CM @ Risk	51	564.7	197.3	27.6243	331	1188
Design Bid Build	86	569	172	18.5456	332	1304
Diff (1-2)		-4.329	181.8	32.1242		

PDM	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
CM @ Risk		564.7	509.2	620.2	197.3	165.1	245.2
Design Bid Build		569	532.2	605.9	172	149.6	202.4
Diff (1-2)	Pooled	-4.329	-67.8607	59.2027	181.8	162.4	206.4
Diff (1-2)	Satterthwaite	-4.329	-70.3918	61.7338			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	135	-0.13	0.893
Satterthwaite	Unequal	93.996	-0.13	0.8968

Method	Equality of Variances Num DF	Den DF	F Value	Pr > F
Folded F	50	85	1.32	0.2637

Variable: CODays (CODays)

PDM	N	Mean	Std Dev	Std Err	Minimum	Maximum
CM @ Risk	51	33.4118	80.5382	11.2776	0	450
Design Bid Build	86	25.6977	52.7442	5.6876	-17	256
Diff (1-2)		7.7141	64.4513	11.3909		

PDM	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
CM @ Risk		33.4118	10.76	56.0635	80.5382	67.3871	100.1
Design Bid Build		25.6977	14.3893	37.0061	52.7442	45.8685	62.064
Diff (1-2)	Pooled	7.7141	-14.8136	30.2418	64.4513	57.5948	73.1756
Diff (1-2)	Satterthwaite	7.7141	-17.4431	32.8713			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	135	0.68	0.4994
Satterthwaite	Unequal	75.785	0.61	0.5432

Method	Equality of Variances Num DF	Den DF	F Value	Pr > F
Folded F	50	85	2.33	0.0006

Variable: PlanPDa (PlanPDa)

PDM	N	Mean	Std Dev	Std Err	Minimum	Maximum
CM @ Risk	51	954	373.6	52.3163	411	2287
Design Bid Build	86	951.4	367.9	39.6755	395	2618
Diff (1-2)		2.6395	370	65.4011		

PDM	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
CM @ Risk		954	848.9	1059.1	373.6	312.6	464.4
Design Bid Build		951.4	872.5	1030.2	367.9	320	432.9
Diff (1-2)	Pooled	2.6395	-126.7	132	370	330.7	420.1
Diff (1-2)	Satterthwaite	2.6395	-127.6	132.8			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	135	0.04	0.9679
Satterthwaite	Unequal	103.85	0.04	0.968

	Equality of Variances			
Method	Num DF	Den DF	F Value	Pr > F
Folded F	50	85	1.03	0.8863

Variable: RPlanPDa (RPlanPDa)

PDM	N	Mean	Std Dev	Std Err	Minimum	Maximum
CM @ Risk	51	987.4	372.7	52.1889	411	2318
Design Bid Build	86	977.1	373.9	40.3158	395	2629
Diff (1-2)		10.3536	373.4	66.0005		

PDM	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
CM @ Risk		987.4	882.6	1092.2	372.7	311.8	463.3
Design Bid Build		977.1	896.9	1057.2	373.9	325.1	439.9
Diff (1-2)	Pooled	10.3536	-120.2	140.9	373.4	333.7	424
Diff (1-2)	Satterthwaite	10.3536	-120.4	141.1			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	135	0.16	0.8756
Satterthwaite	Unequal	105.4	0.16	0.8755

	Equality of Variances			
Method	Num DF	Den DF	F Value	Pr > F
Folded F	85	50	1.01	0.9977

Variable: APDa (APDa)

PDM	N	Mean	Std Dev	Std Err	Minimum	Maximum
CM @ Risk	51	1008.3	379.3	53.1149	531	2318
Design Bid Build	86	1023.6	397.5	42.8655	456	2633
Diff (1-2)		-15.3032	390.9	69.082		

PDM	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
CM @ Risk		1008.3	901.6	1114.9	379.3	317.4	471.5
Design Bid Build		1023.6	938.3	1108.8	397.5	345.7	467.8
Diff (1-2)	Pooled	-15.3032	-151.9	121.3	390.9	349.3	443.8

Diff (1-2)	Satterthwaite	-15.3032	-150.6	120

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	135	-0.22	0.825
Satterthwaite	Unequal	109.11	-0.22	0.823

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	85	50	1.1	0.7285

Variable: CScGPcn (CScGPcn)

PDM	N	Mean	Std Dev	Std Err	Minimum	Maximum
CM @ Risk	51	12.4132	24.8368	3.4778	-8.0189	117.8
Design Bid Build	86	15.581	26.2037	2.8256	-18.2418	152.2
Diff (1-2)		-3.1678	25.7059	4.5432		

PDM	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
CM @ Risk		12.4132	5.4278	19.3987	24.8368	20.7812	30.8741
Design Bid Build		15.581	9.9629	21.1991	26.2037	22.7878	30.8338
Diff (1-2)	Pooled	-3.1678	-12.1528	5.8172	25.7059	22.9713	29.1855
Diff (1-2)	Satterthwaite	-3.1678	-12.0484	5.7128			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	135	-0.7	0.4868
Satterthwaite	Unequal	109.68	-0.71	0.4811

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	85	50	1.11	0.6894

Variable: RCScGPcn (RCScGPcn)

PDM	N	Mean	Std Dev	Std Err	Minimum	Maximum
CM @ Risk	51	4.3519	17.5004	2.4505	-31.2169	100.5
Design Bid Build	86	9.2304	22.0136	2.3738	-25	152.2
Diff (1-2)		-4.8785	20.4585	3.6158		

PDM	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
CM @ Risk		4.3519	-0.5702	9.274	17.5004	14.6427	21.7543

Design Bid Build		9.2304	4.5106	13.9501	22.0136	19.1439	25.9034
Diff (1-2)	Pooled	-4.8785	-12.0293	2.2724	20.4585	18.2821	23.2278
Diff (1-2)	Satterthwaite	-4.8785	-11.6314	1.8745			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	135	-1.35	0.1795
Satterthwaite	Unequal	123.76	-1.43	0.1553

	Equality of Variances			
Method	Num DF	Den DF	F Value	Pr > F
Folded F	85	50	1.58	0.0801

Variable: PScGPcn (PScGPcn)

PDM	N	Mean	Std Dev	Std Err	Minimum	Maximum
CM @ Risk	51	6.516	11.9155	1.6685	-4.5822	52.879
Design Bid Build	86	8.1139	13.0614	1.4084	-8.0386	60.9215
Diff (1-2)		-1.5979	12.6491	2.2356		

PDM	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
CM @ Risk		6.516	3.1647	9.8673	11.9155	9.9698	14.812
Design Bid Build		8.1139	5.3135	10.9142	13.0614	11.3587	15.3693
Diff (1-2)	Pooled	-1.5979	-6.0191	2.8233	12.6491	11.3035	14.3613
Diff (1-2)	Satterthwaite	-1.5979	-5.9238	2.728			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	135	-0.71	0.476
Satterthwaite	Unequal	112.92	-0.73	0.4658

	Equality of Variances			
Method	Num DF	Den DF	F Value	Pr > F
Folded F	85	50	1.2	0.4853

Variable: RPScGPcn (RPScGPcn)

PDM	N	Mean	Std Dev	Std Err	Minimum	Maximum
CM @ Risk	51	2.4567	8.9211	1.2492	-20	38.7681
Design Bid Build	86	4.9742	10.54	1.1366	-15.6904	55.5007
Diff (1-2)		-2.5175	9.9711	1.7623		

PDM	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
CM @ Risk		2.4567	-0.0523	4.9658	8.9211	7.4643	11.0896
Design Bid Build		4.9742	2.7144	7.234	10.54	9.166	12.4024
Diff (1-2)	Pooled	-2.5175	-6.0027	0.9677	9.9711	8.9103	11.3208
Diff (1-2)	Satterthwaite	-2.5175	-5.8616	0.8266			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	135	-1.43	0.1554
Satterthwaite	Unequal	119.05	-1.49	0.1387

	Equality of Variances			
Method	Num DF	Den DF	F Value	Pr > F
Folded F	85	50	1.4	0.2023

Variable: PlnSFDa (PlnSFDa)

PDM	N	Mean	Std Dev	Std Err	Minimum	Maximum
CM @ Risk	51	152.6	58.7095	8.221	52.8487	333.3
Design Bid Build	86	158.7	71.5219	7.7124	50.1847	357.9
Diff (1-2)		-6.0871	67.0626	11.8524		

PDM	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
CM @ Risk		152.6	136.1	169.2	58.7095	49.1228	72.9805
Design Bid Build		158.7	143.4	174.1	71.5219	62.1983	84.1597
Diff (1-2)	Pooled	-6.0871	-29.5275	17.3533	67.0626	59.9283	76.1403
Diff (1-2)	Satterthwaite	-6.0871	-28.4029	16.2287			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	135	-0.51	0.6084
Satterthwaite	Unequal	121.42	-0.54	0.5902

	Equality of Variances			
Method	Num DF	Den DF	F Value	Pr > F
Folded F	85	50	1.48	0.1315

Variable: CFPlnDDa (CFPlnDDa)

PDM	N	Mean	Std Dev	Std Err	Minimum	Maximum
CM @ Risk	51	28784.4	11133.4	1559	10143.3	54817

Design Bid Build	86	22924.9	11055.4	1192.1	7291.9	62882
Diff (1-2)		5859.5	11084.3	1959		

PDM	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
CM @ Risk		28784.4	25653.1	31915.7	11133.4	9315.4	13839.7
Design Bid Build		22924.9	20554.6	25295.2	11055.4	9614.2	13008.9
Diff (1-2)	Pooled	5859.5	1985.2	9733.8	11084.3	9905.2	12584.7
Diff (1-2)	Satterthwaite	5859.5	1967.9	9751.1			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	135	2.99	0.0033
Satterthwaite	Unequal	104.54	2.99	0.0035

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	50	85	1.01	0.9383

Variable: NotReady (NotReady)

PDM	N	Mean	Std Dev	Std Err	Minimum	Maximum
CM @ Risk	51	312.9	254.6	35.6563	23	1144
Design Bid Build	86	347.4	278.6	30.0419	0	1338
Diff (1-2)		-34.5087	270	47.7137		

PDM	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
CM @ Risk		312.9	241.3	384.5	254.6	213.1	316.5
Design Bid Build		347.4	287.7	407.2	278.6	242.3	327.8
Diff (1-2)	Pooled	-34.5087	-128.9	59.8543	270	241.3	306.5
Diff (1-2)	Satterthwaite	-34.5087	-126.9	57.8659			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	135	-0.72	0.4708
Satterthwaite	Unequal	112.76	-0.74	0.4608

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	85	50	1.2	0.4945

Appendix L

Survey Respondent Comments

Quality of Workmanship provided by the Construction Team

CM at-Risk

- Good cost database for estimating, experienced field supervision team
- Site Work quality - Very Satisfied
- This school was a re-use design from a previous school we built. CM firm built the previous school and had some familiarity with the design.
- Very satisfied, CM was responsive to all my concerns
- The (Construction Manager) was terminated as CMAR after this project was completed due to cost over runs, etc.
- Satisfied with quality of workmanship provided by the Construction Team.
- Wiring was dissatisfied
- Very experienced CM firm did this project
- Communication with Owner

Design-Bid-Build

- Site work - Very Dissatisfied
- Overall we're satisfied with the Quality of Workmanship. There were very difficult unforeseen site conditions to overcome and the GC seemed to deal with those challenges fairly well.
- Very satisfied overall
- The GC did an excellent job scheduling, coordinating and managing work on this project.
- Several of the subcontractors failed to perform well and the GC was very ineffective in getting them to improve their performance
- N/A
- Some of the subcontractors work on the project left the owner with ongoing problems
- I do not understand this question
- CM firm used was same firm that built two previous schools for us but this was the first time they built a middle school.
- We've had some problems with electrical work but overall are very pleased with the final building project.
- Response time on punch list items was at times slow. In some cases, after warranty period problems were not solved by the construction team.

Figure L-1: Survey Respondent Comments.

Construction Team Management Services

CM at-Risk

Quality was good CM provided all required services in a timely manner with no excuses.

Satisfied with the construction management on the project.

Satisfied

Great relationship between the design team, the CMAR, and the District.

Design-Bid-Build

I was not in this position when the school was constructed

There were some problems adjusting for the site conditions that impacted cost and schedule. Not all on the GC but it really was a team issue.

The project was completed in a timely manner despite very wet weather conditions for extended periods and site access challenges.

The site contractor on this project was terrible. The GC lacked continuity in staff on the project which led to scheduling delays and cost problems.

Had problems with the work of one of the subcontractors that resulted in significant problems after occupancy.

Very Sat, TABS-Very Sat, 3rd party Div. 1/17 Inspection-Very Sat

The overall construction management was handled well by the general contractor.

A limited number of subcontractors presented certain problems but overall the project quality was very good.

Design Team Professional Services

CM at-Risk

Designer was cooperative and resolved issues quickly

Very satisfied except for design on the security system.

Very experienced design team for this project. This project was a hybrid of a prototype design and was customized to meet our needs.

Design-Bid-Build

This information was provided from other staff that was here at the time of construction

This was a site adapt of a prototype with some modifications in plan that could have been handled better in my opinion.

The project was a prototypical designed school modified for this site. Even with that, there were a substantial number of RFI's and change orders.

Figure L-2: Survey Respondent Comments.

Difficulty with the A/E in following up on warranty and workmanship issues following occupancy.

We have had some problems with a lack of details or instructions to the contractors as well as product selections that have led to post construction issues

This design was a duplicate of (another school) design.

The team did two projects using a similar plan and we were very pleased with the design team efforts.

The design team did a great job in providing a very high quality of service on the project.

Project Team Relationship

CM at-Risk

The geographical distance between the design team and the project location presented challenges.

This team worked on several previous school projects for us.

Cooperation is key however all must understand that the Owner makes all final decisions

Neither firm had much experience with the other but the project went very well.

Department of Education Requirements for Capital Outlay Reimbursements - Very Satisfied

Design-Bid-Build

The project delivery method utilized for the project is not conducive to fostering strong team relationships. At times they can be adversarial as a result.

The lack of timely communication often led to delays and misunderstandings among the various contractors at the site.

The nature of this process does not allow for collaboration of the design and construction team members.

Though not an integrated design approach, this team worked well together in addressing issues and getting the project completed on a very tight schedule.

Although the general level of communication was OK, the contractor was difficult to deal with when it came to change orders on hidden condition issues.

Figure L-3: Survey Respondent Comments.

Important Considerations for Delivery Method Selection

CM at-Risk

- Our School Board is fixated on cost and change orders as primary reason for delivery method. Administration focused on quality.
- This school was a re-use of a previous design. Board was interested in additional cost savings by using a re-use design. Administration was interested in quality improvements and improvements in design by using a re-use design and CM delivery method.
- Method of delivery can be influenced greatly by size and scope of the project.
- Our School Board is focused on cost reductions while the Administration is focused on quality of the finished product.

Design-Bid-Build

- Project cost, project schedule and how complex the project is.
- This school was a re-use design and a duplicate of (another school). Our Board had a tight time frame and wanted to reduce cost using this delivery method as (other school) was under construction at the same time. Board was interested in cost efficiencies with two identical schools under way at the same time.

Project Delivery Method Effectiveness

CM at-Risk

- Delivery method along with fact that this school was a re-use and same team as previous school allowed contractor to be more in-depth with design analysis and produced more suggestions on cost savings and quality design. This school finished less expensive and better in overall quality than first school by same team. Delivery method provided channel for better collaboration during design.
- CM firm was very engaged in the design process and gave very good critiques of constructability and long term maintenance items.

Design-Bid-Build

- This process is not well suited to getting the best price for the best building that the budget can purchase.
- I feel that this project delivery method is only minimally effective and almost depends more on chance rather than on using a method that features building a strong team.
- This process doesn't allow the owner to have an integrated team approach thereby limiting the effectiveness of the design/construction team members

Figure L-4: Survey Respondent Comments.

The Construction Project Manager made poor decisions to delay the schedule. So I answered the process was fine, but the manager made schedule judgment errors

The design process was very traditional and not an integrated process. It lacked taking advantage of the contractor's experience and knowledge of constructability.

In the public sector and in utilizing the Design/Bid/Build project delivery method, general contractors are often required to use subcontractors that they may not know or that are less than desirable but their bid figure is lower than other contractors and the GC needs to keep the price down in order to be competitive.

This delivery method is not effective in my opinion to giving taxpayers the best value for the dollars spent.

The method does not provide the best solutions or the best construction in all cases due to the lack of integrated efforts by all team members during the design phase.

(One of our other projects) was several months ahead of this school. Lessons learned at (that school) helped this school during construction. It made this project smoother as CM delivery allowed CM to study the other project and plan ahead better for this one.

The process, in my opinion, leaves much to be desired and depends entirely on the willingness of the parties to cooperate to achieve a mutually beneficial outcome.

Even with reasonable due diligence on the part of the A/E and owner, it's difficult using the Design/Bid/Build method to control the subcontractors that are selected by the GC and control their quality of workmanship.

Figure L-5: Survey Respondent Comments

Appendix M

Summary of Cost and Time Empirical Findings

Cost Metric	Method	Mean	p-value
Original Construction ($)	Design-Bid-Build	$20,960,467	
	CM at-Risk	$26,001,207	
	Difference	$5,040,740	0.0148
Final Construction Cost ($)	Design-Bid-Build	$21,280,286	
	CM at-Risk	$26,101,221	
	Difference	$4,820,935	0.0230
Original Project Cost ($)	Design-Bid-Build	$22,023,229	
	CM at-Risk	$27,141,092	
	Difference	$5,117,863	0.0180
Final Project Cost ($)	Design-Bid-Build	$22,427,554	
	CM at-Risk	$27,436,298	
	Difference	$5,008,744	0.0250
Construction Cost Growth (%)	Design-Bid-Build	1.25%	
	CM at-Risk	0.32%	
	Difference	0.93%	0.2249
Project Cost Growth (%)	Design-Bid-Build	1.45%	
	CM at-Risk	1.04%	
	Difference	0.41%	0.6004
Unit Cost ($/SF)	Design-Bid-Build	$148.80	
	CM at-Risk	$191.60	
	Difference	$43	<0.0001
Student Cost ($/Student)	Design-Bid-Build	$20,915.60	
	CM at-Risk	$27,057.00	
	Difference	$6,141	<0.0001

Time Metric	Method	Mean	p-value
Actual Construction (Days)	Design-Bid-Build	569.0	
	CM at-Risk	564.7	0.8930
	Difference	4.3	
Actual Project (Days)	Design-Bid-Build	1,023.6	
	CM at-Risk	1,008.3	0.8250
	Difference	15.3	
Construction Schedule Growth (%)	Design-Bid-Build	9.23%	
	CM at-Risk	4.35%	0.1795
	Difference	4.88%	
Project Schedule Growth (%)	Design-Bid-Build	4.97%	
	CM at-Risk	2.46%	0.1554
	Difference	2.51%	
Project Intensity (SF/Day)	Design-Bid-Build	158.7	
	CM at-Risk	152.6	0.6084
	Difference	6.1	
Project Intensity ($/Day)	Design-Bid-Build	$22,924.90	
	CM at-Risk	$28,784.40	
	Difference	$5,859.50	0.0033
Readiness	Design-Bid-Build	347.40	
	CM at-Risk	312.90	
	Difference	34.50	0.4708

GLOSSARY

The literature reveals that there are currently no universally accepted definitions for the individual methods of project delivery (Kenig, 2011); however, there is an ongoing movement driven by both the Associated General Contractors (AGC) and the American Institute of Architects (AIA) in an effort to standardize the language utilized to discuss these methods. Therefore, for the purpose of this study, the most recent combined AIA/AGC publication on the subject, *Project Delivery Systems for Construction*, (Kenig, 2011) will be utilized for these definitions as described below.

Project Delivery Method – The comprehensive process of assigning contractual responsibilities for designing and constructing a project to include:

- Definition of the scope and requirements of a project
- Contractual requirements, obligations, and responsibilities of the parties
- Procedures, actions, and sequences of events
- Interrelationships among the participants
- Mechanisms for managing time, cost, safety, and quality
- Forms of agreement and documentation of activities

Design-Bid-Build – A project delivery method where the owner procures a design and bid package from an independent designer, uses a competitive procurement process to get bid prices for all work required to build the project as specified, and then selects a constructor to build the project on the basis of either Low Bid or Best Value: Total Cost procurements.

Construction Management at-Risk (CM at-Risk) – A project delivery method where the owner selects an independent designer to provide a design package, and also selects a separate CM at-Risk to provide construction services. The CM at-Risk combines the skills and services of the Agency Construction Manager and the traditional General Contractor (GC) providing essential preconstruction services with general contractor services. The CM at-Risk holds the trade contracts and is responsible (at-Risk) for both the schedule and performance of the work by either its own workers or specialty subcontractors. The defining characteristics of CM at-Risk are: 1) design and construction are separate contracts and 2) the total construction cost is not a factor in the final selection.

Glossary (continued)

Design-Build – A project delivery method where one firm assumes responsibility for both the design and the construction of the project (within a single contract). By combining these two functions from the outset of the project, Design-Build can promote an interdisciplinary team approach throughout the duration of the project.

Agency Construction Management – A project management system based on an owner's agreement with a qualified construction management firm to provide coordination, administration, and management within a defined scope of services. This term, often referred to as CM, Agency-CM, or CM-Agency is a management method and *not* a project delivery method and therefore, it will not be considered or explored within the current research study.

Best Value – the most advantageous balance of cost, time, and quality performance as determined by an owner to meet the construction requirements of a particular project.

Best Value Selection – "a selection (procurement) process for construction services where total construction cost, as well as other non-cost factors, are considered in the evaluation, selection, and final award of construction contracts"(AGC-NASFA, 2006).

Claims – a disagreement between the owner and contractor regarding a contractual issue involving the cost, time, or quality of the work that cannot be resolved during the construction period. (AIA, A201- 2007, General Conditions of the Contract for Construction, Article 15.1).
For the purpose of this research, a claim or dispute is an issue of cost, time, or quality that could not be resolved during the construction contract term and required mediation, arbitration or litigation in order to resolve it.

Public Schools - for the purpose of this research, this term refers only to public schools, grades K-12.

Reimbursable expenses - out-of-pocket expenses incurred by the architect on behalf of the owner, such as long-distance travel and communications, reproduction of contract documents, and authorized overtime premiums. Detailed in the owner-architect agreement, they are usually in addition to compensation for professional services and are normally billed as they occur. (AIA, 2014).

Glossary (continued)

Variables and Metrics

Original Construction Cost ($) - the measure of cost originally contracted to complete all work required to construct the school facility. It includes the originally contracted construction cost plus any preconstruction cost and/or other separate contract costs and was computed as:

Original Construction Cost ($) = Original Contract Cost ($) + Preconstruction Cost ($) + Other Cost ($)

Original Project Cost ($) - the measure of cost originally contracted to complete all work required to design and construct the school facility. It includes the Original Construction Cost plus the Original Design Cost and was computed as:

Original Project Cost ($) = Original Construction Cost ($) + Original Design Cost ($)

Final Construction Cost ($) - the measure of total cost to complete all work required to construct the school facility. It includes the Original Construction Cost and any costs associated with change orders, fees, or other adjustments and is computed as:

Final Construction Cost ($) = Original Construction Cost ($) + Change Orders, Fees, Adjustments Costs ($)

Final Project Cost ($) - the measure of total cost to complete all work required to design and construct the school facility. It includes the Final Construction Cost and Final Design Cost and is computed as:

Final Project Cost ($) = Final Construction Cost ($) + Final Design Cost ($)

Construction Cost Growth (%) - the percentage of cost growth (positive or negative) over the duration of the construction period. It reveals variability due to the construction cost of changes and is computed as:

Cost Growth (%) = [(Final Construction Cost ($) – Original Contract Cost ($)) / Original Contract Cost ($)] * 100

Project Cost Growth (%) - the percentage of cost growth (positive or negative) over the duration of the project period. It reveals variability due to the design and construction costs of changes.

Cost Growth (%) = [(Final Project Cost ($) – Original Contract Cost ($)) / Original Contract Cost ($)] * 100

Unit Cost ($/SF) - the square foot cost of construction for a school facility and was determined by dividing the Final Project Cost by the Gross Square Foot area of the school facility:

Glossary (continued)

Unit Cost ($/SF) = Final Project Cost/Facility Gross Square Foot

Student Cost ($/Student) - the per student cost of construction for a school and was determined by dividing the Final Project Cost by the Student Capacity of the facility:
Student Cost ($/Student) = Final Project Cost/Facility Student Capacity

Gross SF – the gross square foot area of building space constructed

Planned Construction (Days) - the contracted construction duration in days. It was derived by counting the number of days between the Construction Start date and the Original Completion date. Alternatively, it was sometimes listed in the construction contract.

Actual Construction (Days) - the actual construction duration in days. It is derived by counting the number of days between the Construction Start date and the Substantial Completion date.

Planned Project (Days) - the project duration in days. It is derived by counting the number of days between the Design Start date and the Original Completion date.

Actual Project (Days) - the actual project duration in days. It is derived by counting the number of days between the Design Start and the Substantial Completion date.

Construction Growth (%) - the percentage of time growth (positive or negative) over the duration of the construction period. It reveals the time variations (overruns or underruns) required to complete the construction. Construction Growth (%) = [(Actual Construction (Days) – Planned Construction (Days)) / Planned Construction (Days)] * 100

Project Growth (%) - the percentage of time growth (positive or negative) over the duration of the design and construction periods. It reveals the time variations (overruns or underruns) required to complete the project.
Project Growth (%) = [(Actual Project (Days) – Planned Project (Days)) / Planned Project (Days)] * 100

Project Intensity (SF/Day) - utilized as a measure of productivity showing the square foot area of school facility constructed per schedule day and is derived:
Project Intensity (SF/Day) = Facility Gross SF/Actual Project (Days)

Glossary (continued)

Project Intensity ($/Day) - utilized as a measure of productivity showing the volume of work ($) completed per schedule day and is derived:
Project Intensity ($/Day) = Final Project Cost ($)/Actual Project (Days)

Quality – the manner in which the project met the expectations of the owner:

- Building Product in terms of:
  - the project workmanship including the building exterior and interior, heating, ventilation, and air conditioning (HVAC), plumbing, and lighting systems
  - the building readiness in terms of:
    - the number of days between the date of substantial completion and the date the final payment was approved for construction services, which establishes the amount of time required to finish all open items of work
    - the owner's records of warranty and callback issues during the first 90 days of building operations
- Service in terms of:
  - the responsibilities of the project team members
  - the control of the project cost, schedule, quality, or other owner determined requirements

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